1981

Symposium Proceedings - Situation Management of Two Intermountain Species: Aspen and Coyotes, Part I Aspen Aspen

Norbert V. DeByle

SYMPOSIUM PROCEEDINGS

SITUATION MANAGEMENT OF TWO INTERMOUNTAIN SPECIES:

ASPEN AND COYOTES

Volume I

Aspen

Norbert V. DeByle, editor

Utah State University

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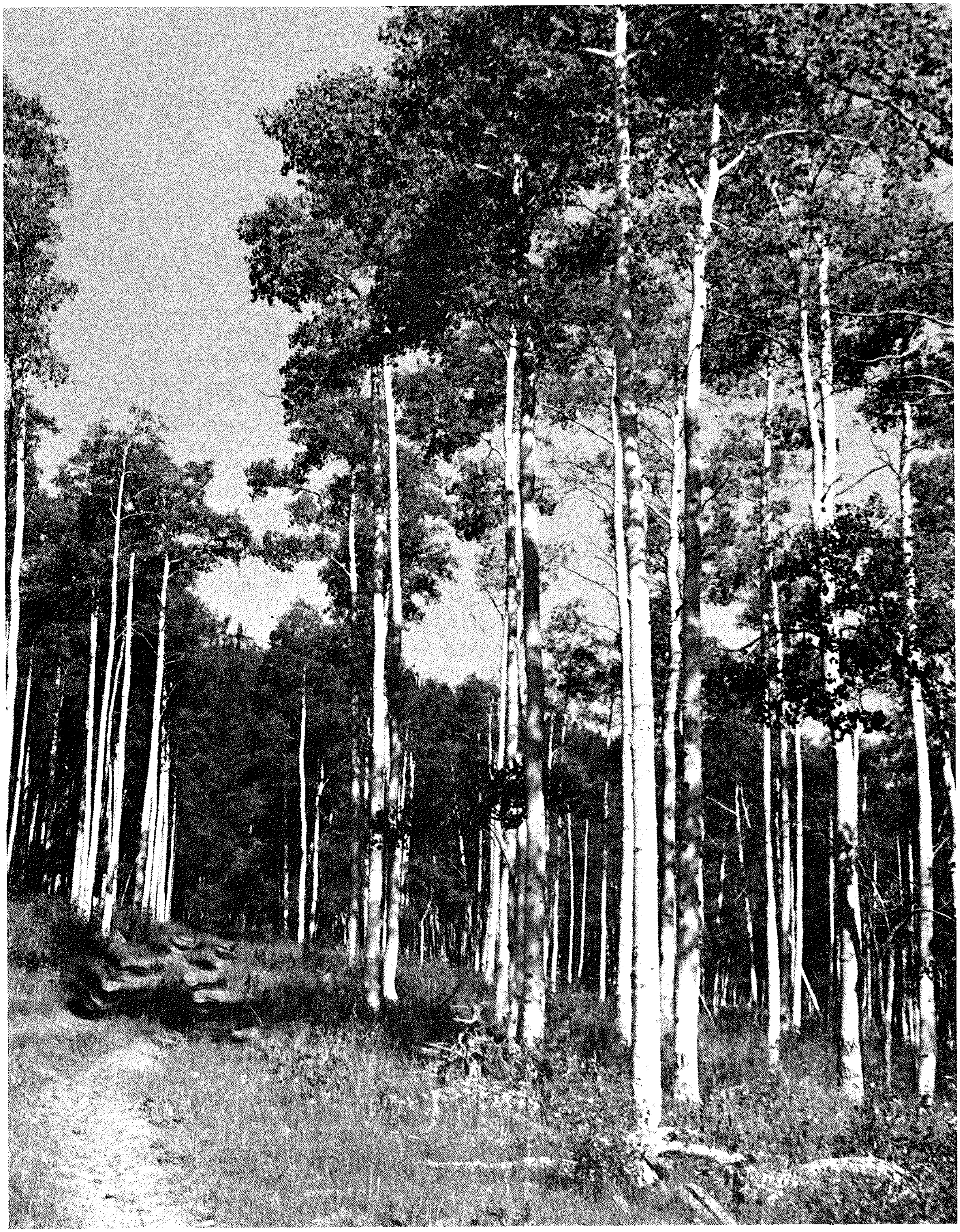

FOREWORD

Several million people and several million acres of aspen throughout the Intermountain West, when brought together, are certain to spark interest. The photographer views aspen on our mountains with aesthetic appreciation; the hunter sees the type as habitat for the pursued species; the rancher looks to the forage growing in the understory; the logger sees the rapid production of wood fiber for many, albeit limited, products; the homeowner with a fireplace or stove views these trees as a source of inexpensive and clean fuel; the nurseryman thinks of aspen as a rapid-growing, deciduous shade tree; and the recreationist enjoys the shade, rustling leaves, and pleasing environment of the aspen forest.

Because of all these special interests, and the wide distribution of aspen, we have many situations in which management systems differ--at least different end-products are emphasized. Yet there is a commonality to the management techniques that can be successfully employed.

Several scientists and managers combined their talents and experiences to produce the 11 papers published in these proceedings. We cover the basic biology of the tree and its ecosystem, several management objectives and activities, and some of the management techniques.

Appreciation is extended to all who participated in the symposium especially the authors for their stimulating papers and David Balph for developing the situation management theme and chairing the planning committee. Thanks, too, to Utah State University for hosting the symposium and for publishing these proceedings.

Norbert V. DeByle
Editor

CONTENTS

VOLUME I

SITUATION MANAGEMENT OF NATURAL RESOURCES

Frederic H. Wagner, Associate Dean,
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It's a great pleasure to welcome you to our 1981 Conservation Week symposium, and an honor for me to kick it off. It's very clear to me that the really dedicated resource managers, the truly committed, are gathered in this hall right now. I know this because there is a jalapeno-pepper-eating contest with a $10 prize going on outside, and that will be followed by a belly-dancing exhibition. That you should be in here proves who the really serious practitioners of the management art are. And we are going to do our best to meet your expectations, to show that trembling aspens and snapping coyotes have it all over trembling bellies and snappy peppers.

The concept of our symposium this year was put forward by a very thoughtful and philosophically minded committee made up of Dave Balph, professor of animal behavior here at Utah State University; Norb DeByle, plant ecologist with the Intermountain Forest and Range Experiment Station based here in Logan; and Fred Knowlton, leader of the Fish and Wildlife Service's Predator Ecology and Behavior Unit also here on campus. This committee asked us to consider the biology and management of these two species in the context of a twin-horned dilemma that has permeated much of human affairs throughout recorded history, and challenges us as teachers in the classroom. I would like to dwell on this briefly in my allotted time today in order to set the stage for the next day and a half of papers.

The dilemma I speak of is the tension between abstract generality on the one hand, and the concrete, or real, or particular on the other. An ivory-tower type like me could get carried away, going off on all sorts of tangents on this theme. Since we're meeting in the halls of academia, I'm going to indulge myself a bit.

For example, I could get carried away as a barbershop philosopher. The question goes back at least as far as Plato who contended that the only true reality was abstract, universal concepts. In the context of our discussion today, it is the idea "aspen" that is the true reality. In the every-day world, each individual tree is only an imperfect and fleeting representation of Plato's true reality, that great aspen in the sky.

In philosophy, the most pervasive revolt against this idea has been the existential movement of the 19th and 20th centuries, which has had a powerful influence on our contemporary culture and public affairs. Existentialism is, in its basic nature or essence--and this raises the hackles of its followers, because the word essence is a dirty word--but it is in essence a protest against abstraction. Its battle cry is: "Existence precedes essence."

In other words, you can't even have the concept "aspen" until there has grown that scrawny, little tree at 9,000 feet, struggling to compete with a bigger Engelmann spruce; or that tall one at 7,000 feet that got up to the sun before the fir understory germinated and got started. In this philosophy, it is only these two trees that have reality, and the concept "aspen" bears only a very poor, and in some ways dangerous, correspondence to them. It is a protest against labels, stereotypes, and categories. Jean Paul Sartre, the French existentialist, declined the Nobel Prize because he did not want to be known as "Sartre, the Nobel Prize Winner." He wanted to be known only as "Sartre."

Now all of this may sound like a far-out, ivory-tower tangent, hardly relevant to the theme of our symposium. But I'll show, first of all, that our symposium title comes from the extension of existentialism into ethics; secondly that the management philosophy proposed for this symposium is in fact existential management; and third, that while we may spend a day and half extolling the virtues of situation management, we do not wish to imply that it is the be all and end all. Let's do air fully the values of modifying management efforts to the needs of particular situations. But we'll surely end up concluding that there is still room in the mix for management by general policy or guideline, and that the ideal is a balance between the two.

First, about the title. The Platonic form of ethics comes down to us in the great institutional moral codes of history: the Koran, the Mosaic Laws, the Ten Commandments. These are put forward as absolute codes of behavior, universally applicable for all to adhere to.

But the existentialists counter that situations can modify what is right or wrong. It might be more humane to lie to someone than tell them the brutal truth. It might be moral to take a life when that of a pregnant woman is endangered, or she is struggling with the agony of rape or incest. In fact, the philosophy is sometimes extended all the way to the position that there are few if any moral absolutes, and every moral decision must be made in the context of the situation prevailing at the time. Ethics, then, become situation ethics. And this is the source of our symposium title, situation management.

Now, as our symposium emphasis might suggest, there appears to be momentum toward situation management. That momentum derives, first of all, from the growing complexity of our society. In the past, we have engaged in single-value, either/or management that followed such slogans as:

"The only good coyote is a dead one..." or

"We should ban all coyote control..." or

"We should only control the offending animal..." or

"There is absolutely no place for toxic agents..."

We can all think of other generalized policies and procedures that have their place, but maybe have been extended too broadly at times and should have been modified to fit local situations: P-J eradication, widespread planting of crested wheatgrass, buck only laws, allotting 25 percent of AUMs to wildlife, rest-rotation grazing, and others.

But the values of our society have become too diverse for single, inflexible management policies or guidelines. Coyotes have very different meanings for Utah sheepmen, Los Angeles suburbanites, Chicago tourists visiting Yellowstone, and Texas deer hunters. Aspens mean something very different to the private land forester in Wisconsin and the public land manager in Utah. Management programs now need to be flexible enough to take this diversity into account and be modified to fit individual situations. Dave Balph calls this "fine-tuning" management.

The momentum toward situation management also derives from the existential changes in our populace itself, and what that has done to political process. Time was when we accepted unquestioningly the authority of central government and its generalized decisions on national policy. If the President and the Congress said we needed a military draft, we went along. If the Secretaries of Interior and Agriculture decreed that there should be more (or less) grazing on public lands in the West, or that there should be regionwide coyote control, we accepted that.

But along with our growing complexity, we have become more assertive. Sagebrush Rebels now challenge the authority of public agencies to make centralized management decisions, or to have any say at all in resource management within their States. The people of Utah and Nevada challenge the decision by the federal government to base the MX missile in their yards, and will block it if they can. Tax-revolt threats arise every few days.

Much of this is surely justified. Without it there could easily be a drift toward generality and simplification. A single, general policy is easier both to decide upon and administer than a mosaic of policies. Such generality becomes insensitive to the particular needs of different situations. The concept "aspen" is too general to explain the scrawny little, snow-bent tree and the tall, close-grown one. If, in addition, power grows at the center, over-generalized policies can be forced on the public without recourse.

It appears that the pendulum has swung pretty far in this direction. So let us, in the next day and a half, move with the times and explore situation management. Let's be responsive to the diverse needs and values of local people and local situations. The concept of our program committee is both timely and imaginative.

I don't think that, in pressing this concept, they have only one oar in the water. They certainly recognize that we still live in a state, a nation, and a world. Things often have to be done in the best interests of those entities when they risk the disfavor and even welfare of people in local situations. And policies set at local levels are vulnerable to local, grassroots political pressures that might work to the detriment of higher levels. As Norb DeByle put it on Tuesday: "We still must have policies set at the national level if we are to have any national goals."

In the final analysis, the best of all worlds is a balance between the two horns of our dilemma. As Douglas Sloan stated in a recent symposium on "Knowledge, Education, and Human Values" sponsored by the Charles F. Kettering Foundation: "Only by maintaining the tension between polarities--between freedom and discipline, between individuals and society, between rationality and instinct--can we hope to address central human problems with any degree of success."

Judging by the current political mood in the country, things are out of balance. So let's accept our program committee's challenge, get on with situation management, and bring the pendulum back toward the center.

Thank you.

ASPEN AND ITS MANAGEMENT: AN INTRODUCTION

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Quaking aspen (Populus tremuloides Michx.) has the greatest natural range of any North American tree species. In the East its distribution is relatively continuous; but in the West it is confined to suitable sites on mountains and high plateaus (fig. 1). Despite the spotty western distribution, two Rocky Mountain States are among the six with more than a million acres of commercial quality aspen forest. Of the six, Minnesota leads the list with more than 5 million acres; then follow Michigan, Wisconsin, Colorado, Alaska, and Utah in descending order. The interior western States have 4.1 million acres of commercial quality aspen (Green and Setzer 1974) among 5.5 million total acres. Aspen acreages in these States are:

State	Commercial	Noncommercial
Colorado	2,288,900	341,000
Utah	1,105,300	145,000
New Mexico	346,100	33,000
Wyoming	187,900	239,000
Arizona	89,900	0
Idaho	60,200	484,000
Montana	44,700	145,000
Nevada	6,500	14,000
TOTAL	4,129,500	1,401,000

Commercial aspen acreage in Colorado and Utah comprises 25 and 31 percent, respectively, of all commercial forests in these States. More of Utah's commercial forest land is occupied by aspen than by any other tree species (Choate 1965). Almost two-thirds of the aspen acreage in the West is in public ownership.

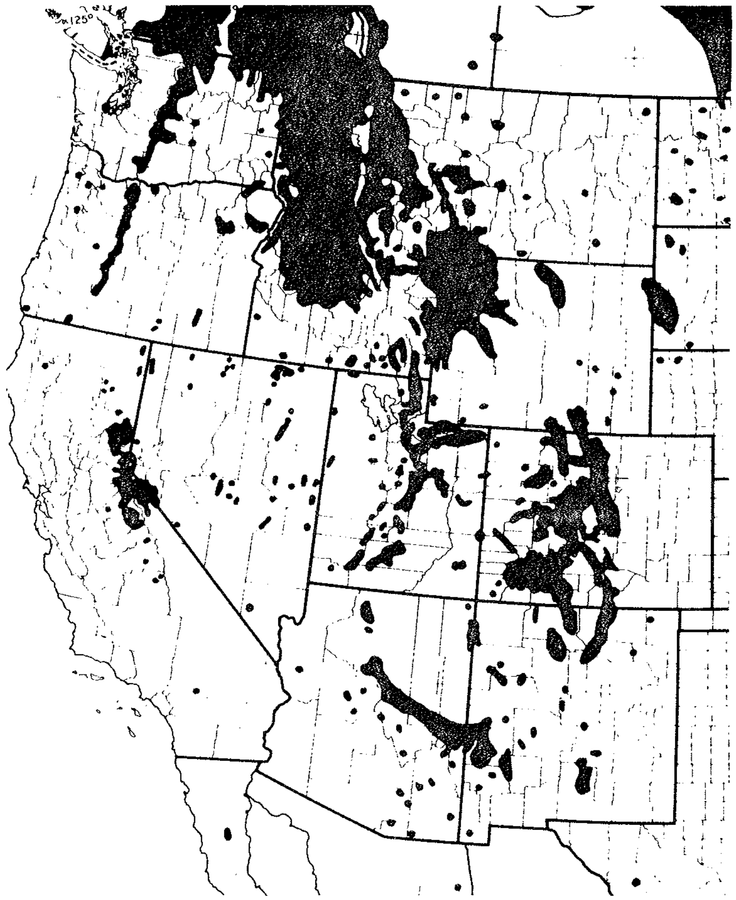

Figure 1.--Distribution of quaking aspen in the western United States (Little 1971)

The Lake States have twice as much cubic-foot volume in aspen than does the West. But the West has slightly more aspen in sawlog-size trees. The Rocky Mountain States have 7,283 million board feet, whereas, the Lake States have 7,181 million board feet in sawtimber (Wengert 1976).

In the semi-arid interior West, aspen is confined to relatively moist sites (16 to more than 40 inches annual precipitation) with a growing season of reasonable length. These conditions restrict this tree to low elevations in the northern portions of its range. Aspen occupies progressively higher elevations southward along the Rocky Mountains. Most commercial sawtimber concentrations are confined to elevations between 7,000 and 10,000 feet in the central and southern Rocky Mountains--in Colorado, northern New Mexico, and southern Utah.

LIFE HISTORY

Aspen is seral on most sites. It invades and pioneers clearings, burns, and other disturbed locations. Later it is replaced by more stable plant communities. Maximum aspen biomass is attained between 50 and 100 years after stand establishment. Sometime between 200 and 400 years after establishment the aspen is often replaced by conifers on most of the cool-wet sites. In the absence of disturbance to regenerate the aspen, shrubs and grass may take over on most of the warm and dry sites. However, some stands, particularly those isolated from conifers, are quite stable. They may continue to occupy a site for centuries without disturbance.

Abrupt destruction of the aspen or mixed aspen-conifer forest, through fire or clearcutting, sets back plant succession and results in a stand of aspen root suckers (fig. 2). Hundreds of suckers may come from the roots of a single parent tree. Therefore, a scattering of aspen trees can be transformed into a complete stand of aspen suckers by destruction of the overstory. Regeneration by seed is unusual throughout much of its range--the requirement of young aspen seedlings for a continuous supply of water is too demanding.

Figure 2.--A dense stand of aspen suckers on a 12-year-old clearcut in the Uinta Mountains

As a result of vegetative reproduction by root suckering, aspen clones have developed over several generations, with each clone occupying from a few square yards to several acres (Barnes 1966). Separate aspen groves are usually separate clones. The stems within a clone are often connected to others through a common parent root system. All trees within a clone are genetically identical. They look alike. They flower at the same time, leaf out at the same time, have the same shaped leaves, have the same color in the autumn, and shed their leaves at the same time. Less obvious similarities are bark color and texture, branch angle, size and form of trees, susceptibility to disease and insect damage, and a host of microscopic and chemical characteristics.

In sharp contrast to similarities within each clone, there are marked differences between clones. A continuous aspen forest is made up of many clones, sometimes intermixed, but each clone usually occupies its own discrete area. The result, particularly obvious in autumn, is a forest consisting of a mosaic of clones (fig. 3).

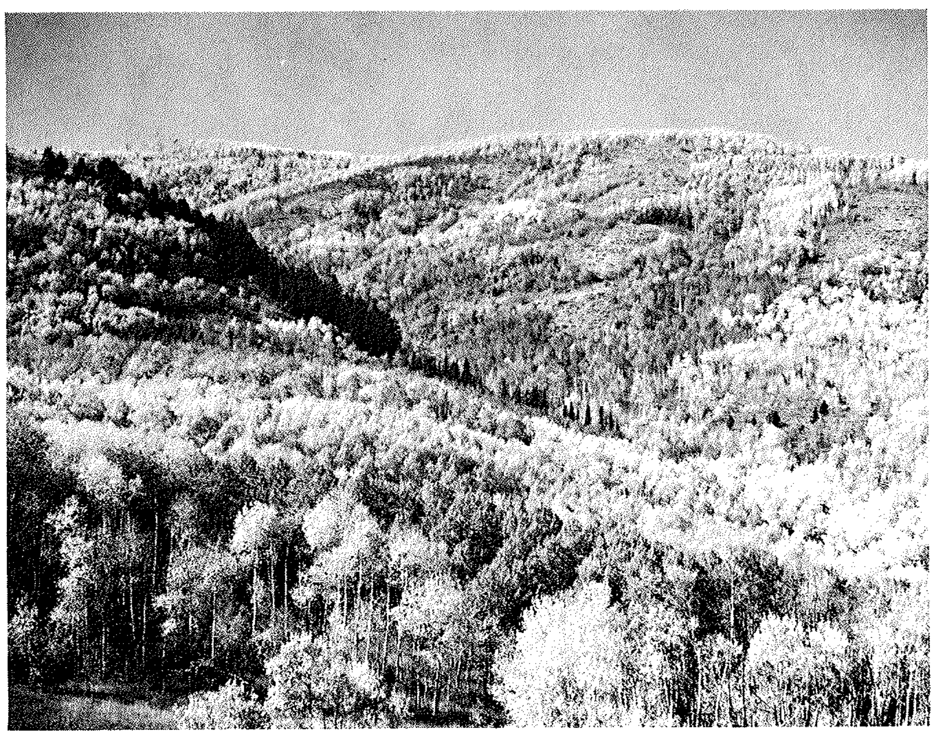

Figure 3.--Vegetative regeneration by root suckering over hundreds or thousands of years has produced distinct aspen clones, each occupying several acres on this aspen-dominated Utah landscape.

Aspen is host for many insects and diseases. A few of them kill. Fungi that cause decay within the trunk reduce utilization potential most. Internal decay is insidious; conks are the only external evidence. Trunk cankers are most obvious, sometimes kill trees, and cause some volume loss. Other diseases, such as black leaf spot, "shepard's crook" on young suckers, and leaf rusts, at times may cause reduction in potential growth but seldom are serious. However, repeated leaf rust epidemics may weaken and indirectly kill trees.

The insects include borers, tent caterpillars, aphids, leaf miners, and many others. Some such as stem borers, may provide access for organisms that cause cankers or decay. Others, such as tent caterpillars, reduce growth and kill trees by defoliation. Most of the rest do little serious tree damage.

Damage to aspen from weather can be extensive. Late spring frosts sometimes defoliate trees in large areas--selecting those clones most vulnerable at the stage of development reached at that time. The trees later grow new leaves, but growth that year is reduced. Also, sunscald often occurs on formerly protected stems opened to direct sunlight through removal or natural mortality of surrounding trees. This weakens and may indirectly kill the damaged trees. Heavy wet snowfall, when aspen are in leaf, causes extensive breakage and often permanently deforms many stems.

VALUES

Aspen forests in the West are truly multiple-use lands. They produce an abundance of wood, water, forage, wildlife habitat, and opportunities for recreation. Despite its high net value, very little concerted effort has been made to maintain and perpetuate aspen. Tradition and economics have prevented effective management of any tree species, such as aspen, that has low or negative dollar value as sawlog stumpage. Current emphasis on wildlife habitat improvement coupled with increasing demands for fuelwood and specialty products such as paneling and shingles are resulting in more aspen management than we have experienced in decades.

How much of each of the resources can we expect from a typical Rocky Mountain aspen stand? Averaged over a 100-year rotation, a top-quality site produces wood at the rate of 80 ft^3 or more net growth per acre per year. But many sites produce from 20 ft^3 (the minimum rate to qualify as commercial forest land) to 40 ft^3 annually.

Water production from the aspen ecosystem depends upon the amount of precipitation, its annual distribution, and the site characteristics influencing effective rooting depth. A typical Utah or Colorado aspen stand yields 10 to 12 inches of water each year to streamflow or to groundwater aquifers (Fig. 4). The aspen type provides excellent watershed protection--the quality of streamflow is high because virtually all of it percolates through porous soil and enters streams as interflow.

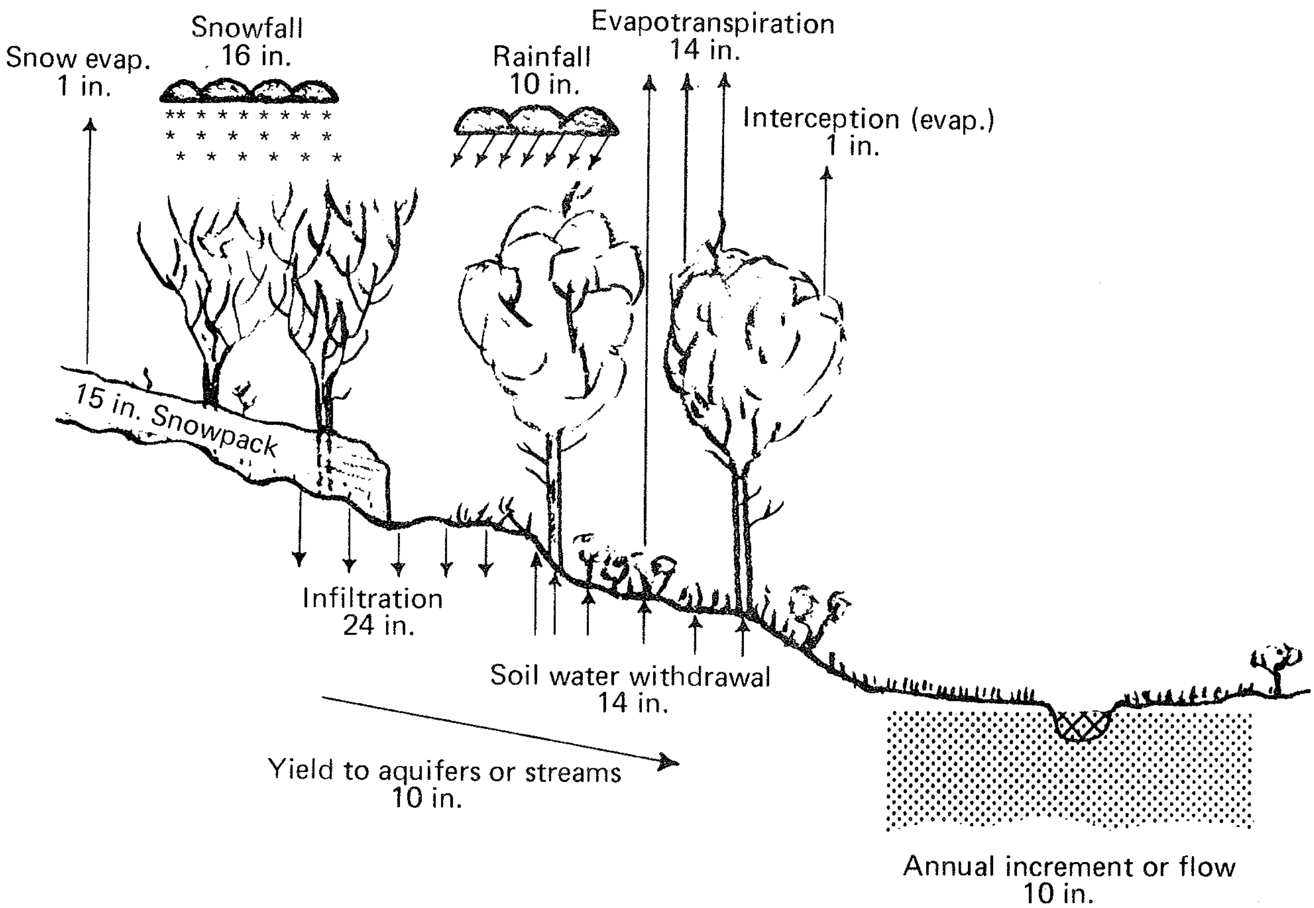

Figure 4.--Annual water balance in a typical western aspen stand.

Forage production, like water and wood, will vary greatly from site to site. From 1,000 to 2,000 lb/acre of undergrowth production suitable for livestock or big game are grown annually under typical Rocky Mountain aspen stands (Houston 1954;

Youngblood and Mueggler 1981). No other western forest type produces nearly this much; conifers typically yield only 300 to 400 lb/acre. Many managers and users consider the aspen type essentially a range rather than a wood-producing forest. It is sought after for summer sheep and cattle range--producing as much forage as many grasslands.

A mosaic of aspen forest, conifer forest, open grassland, and mountain meadows on our western mountains provides ideal habitat for a large variety of wildlife. In the aspen forest, a palatable brushy and herbaceous understory as well as small aspen trees offer big game forage and browse. Aspen is used largely as summer range, but where snow is not too deep, it provides elk winter range, too. In winter, deer are usually forced out of the aspen and onto lower elevation ranges by snow, and moose generally move to willow bottoms for browse. The aspen type also provides ideal habitat for a large variety of tree- and ground-nesting birds, including grouse. Beaver along mountain streams are sustained by aspen and, to a lesser extent, willow.

If markets for aspen develop in the West during the next quarter century, then clearcutting techniques somewhat similar to those used in the Lake States' aspen may be applied. But without markets to pay management costs, thousands of acres of a valuable and potentially renewable resource likely will slowly disappear. Enough money through traditional funding for public land management has not been available to clearcut or burn sufficient acres of mature or derelict aspen to assure their regeneration. Further, destroying an apparently healthy forest with fire, cutting, or herbicide spraying without using the wood appears wasteful and destructive. Yet, this is exactly what must be done on many acres of our western aspen or a large portion will be replaced with conifers, brush, or grass.

There is hope. During the past decade an unexpected rise in the demand for fuelwood has permitted economical harvest of aspen and thus its potential management in the more accessible areas. There also has developed a growing demand for high-quality aspen sawtimber. It is appearing on the market as lumber and is becoming accepted for appropriate uses. At the same time, there is a growing awareness of this type as wildlife habitat. There has been a marked increase in efforts to manipulate aspen through both cutting and burning for habitat improvement in recent years. If these trends continue, aspen will be retained as a forest cover type on much of the western lands it now occupies. An unusual species indeed--by seemingly destroying it we perpetuate it.

Recreation is provided in many forms. Aspen is aesthetically pleasing. Its texture and its variation are desirable both as foreground and as background vegetation, especially in juxtaposition with conifer patches. Autumn coloration of aspen attracts thousands of people to the Rocky Mountains for viewing and appreciation. Aspen groves are comparatively open and yet provide pleasant shade for summer recreationists. Dispersed recreation in aspen is quite acceptable; but experience has clearly shown that concentrations of people in developed campgrounds will destroy an aspen grove in a few years (Hinds 1976). The variety of wildlife inhabiting aspen forests provides abundant viewing and hunting opportunities. The winter recreationist chooses aspen over conifer areas for cross-country skiing, downhill ski runs, and snowshoeing.

Aspen is a natural firebreak (Fechner and Barrows 1976). A pure aspen stand is difficult to burn even under dry conditions. Crown fires, burning completely out of control in conifer stands, will drop to the ground and often extinguish themselves upon reaching an aspen stand. A mosaic of aspen patches and stringers on the landscape breaks up highly flammable conifer forests into manageable units.

MANAGEMENT PROBLEMS AND OPPORTUNITIES

In the East, particularly in the Lake States, aspen is used extensively for wood products, especially as pulpwood. But in the West its value as a wood-producing species is greatly overshadowed by the abundant conifer forests. Forest land managers are interested in this multiple-use type in the West, but little has been done to place aspen under effective management.

The opinions of many western forest managers were recently surveyed to assign relative importance to the many values and uses. This group placed wildlife habitat as the top value. They ranked aesthetics next in importance, followed in order by recreation, water, livestock forage, and wood products. Generally, they felt that aspen wood products would become more valuable in the future, but not to the point of controlling management policy.

Since no single value dominates in aspen--it is the closest of any vegetation type to fitting a multiple-use concept--management is complicated. It is economically and socially much more difficult to manage a type such as this on public lands than a type associated with one dominant use.

In contrast, from the biological standpoint, aspen is relatively easy to manage. The facts that aspen is seral on most sites and that profuse sucker reproduction occurs after stand destruction, provide keys to aspen silviculture and management.

If the seral nature of aspen is to be used for its management, an assumption must be made--that we wish to maintain aspen on much of the land it now occupies. On many sites its multiple values, when added together, exceed those of the plant communities replacing it. With this assumption in mind, the sampled group of forest managers listed the following problems:

1. An adequate market for aspen wood products in the mountainous West is lacking.

2. If the trees cannot be sold and cut, and thus regenerate this seral forest, how are viable stands of aspen going to be maintained in the face of conifer invasion on most sites; and in the face of degradation due to ungulate use, insects, and diseases on many others?

3. Over the array of aspen in the West, how can both site and resource potential be recognized so proper decisions are made for retaining aspen or replacing it on a site-by-site basis? If it is retained, how shall it be managed on each site?

The second key to management--the fact that a profusion of root suckers develops when the aspen overstory is destroyed--makes the above problems easier to cope with. Natural abrupt stand destruction usually is caused by wildlife. Man's techniques to accomplish this same end may include prescribed fire, clearcutting, herbicide spraying, or a combination of these.

If the aspen wood can be utilized, this seral type may be maintained by clearcutting. Then management, for the most part, is accomplished through enforcement of the specifications in logging contracts. Other values may be protected or enhanced by controlling size and shape of clearcuts, harvesting methods, number and location of roads, and aspen rotation age. However, in the West much of the aspen is relatively inaccessible, far from markets, scattered, and occurs on mountainous terrain. Its value, therefore, is currently too low to warrant eonomical harvest by clearcutting.

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ASPEN REGENERATION

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ABSTRACT

Aspen (Populus tremuloides Michx.) typically occurs in clones produced asexually by root suckering. Seedling establishment is rare due to short-lived seed and demanding seedbed requirements. Most suckers arise from preexisting shoot primordia that are initiated in the cork cambium. Cytokinin produced in roots stimulates suckering while auxin translocated from crowns inhibits it (apical dominance). Disturbances that increase the cytokinin:auxin ratio result in sucker production. Clearcutting is the most efficient method of obtaining aspen regeneration because it reduces apical dominance to a minimum and enables shoots of this shade intolerant species to grow in full sunlight.

Aspen regenerates by seed and vegetatively by root suckers (adventitious shoots). If aspen were solely dependent on seed to regenerate itself, it's doubtful that it would be the most widely distributed tree species in North America. Aspen's clonal growth habit enables it to survive in the dryer parts of its range, such as the mountains of Utah and Colorado, where seedling establishment is rare.

Why are seedlings rarely found in this region? It isn't due to the lack of viable seed, as was once thought, because some seed is usually produced each year and germination percentages of fresh seed are high, commonly exceeding 95 percent (Winton and Einspahr 1981). The scarcity of seedlings is due to short-lived seed, insufficient soil moisture at the time of seed dispersal, and demanding seedbed requirements (Maini 1968; McDonough 1979; Winton and Einspahr, in press). Under natural conditions, the tiny, nondormant seed is viable for only 2 to 4 weeks. Seed dispersal occurs in June or early July when there is little precipitation and seedbeds are dry. High and continuous availability of water is critical for the survival of the small, delicate, succulent seedlings (McDonough 1979). They are very intolerant of moisture stress and high temperatures at the soil surface.

In those parts of aspen's range where summer precipitation is sufficient, as in the Lake States, seedling establishment is common (Andrejack and Barnes 1969). That is the reason the size of the clones in these areas are smaller than they are in the Rockies.

All aspen clones, of course, must have at one time originated from a seedling. In the case of Utah aspen, this perhaps means going back in geologic time to the Pleistocene, when the climate in this region was wetter and more suitable for the establishment of aspen seedlings (Baker 1925; Barnes 1975). Thousands of years of vegetative regeneration (successive generations of shoots arising on a continually expanding root system), in which wildfires played an important role, produced the large clones that exist today. Some of the more successful are over 100 acres in size and contain as many as 50,000 ramets (Kemperman and Barnes 1976). No other plant species exists in which single genotypes dominate such large areas of land.

In addition to producing root suckers, aspen also regenerates vegetatively by stump and root collar sprouts; however, these are not common (Baker 1918; Maini 1968). They occur with the greatest frequency (<20 percent) when sapling size or younger aspen are killed.

Aspen's shallow, widely-spreading root system, consisting of numerous long, cord-like lateral roots, makes it well adapted for sucker regeneration and clonal development. Suckers arise from meristems initiated in the bark near the cork cambium (Brown 1935; Sandberg 1951; Schier 1973a). These primordia may develop into buds and then elongate into shoots.[1] Frequently, however, growth is arrested at the primordial stage. Development may not be continuous because the physiological requirements for the initiation of a sucker is different from that for its growth. Thousands of suppressed shoot primordia in various stages of development occur on roots of most clones. These appear to be

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[1] At the same time that shoot development is occurring, the vascular strand is extending, by dedifferentiation of bark tissue, to the root cambium. Eventually vascular connections are established between the shoot and the parent root.

the most important source of shoots when a stand is cut or burned. Rejuvenation (reversion of an adult plant to the juvenile phase) occurs during sucker initiation; this has enabled clones to maintain their vitality during many years of vegetative regeneration (Bonga 1980).

Sucker formation in aspen roots is regulated by the action and interaction of hormones. Cytokinins synthesized in roots stimulate the initiation and growth of suckers (Peterson 1975). Suckering, however, is inhibited by auxin translocated to the roots from growing shoots and leaves, a phenomenon called apical dominance (Farmer 1962; Eliasson 1971a, 1971b; Schier 1973b, 1975a, 1981). To maintain auxin at inhibitory levels it must be continuously supplied because it is rapidly metabolized (Eliasson 1971b, 1972). As long as the cytokinin:auxin ratio is low, suckering will be suppressed (Winton 1968; Wolter 1968). Disturbances that damage, cut, or kill stems will reduce the flow of auxin into the roots and result in aspen regeneration.

If a clone is cut or burned in spring or early summer, shoots will arise the same year. If treatments are carried out after aspen becomes dormant in late summer, suckering will be delayed until the following spring (Schier 1978).

Girdling (removal of a strip of bark from around the stem) might be expected to stimulate suckering because flow of auxin to the roots via the phloem is stopped. In reality, girdling results in production of few suckers (Schier 1978; Schier and Smith 1979). In fact, it's the most efficient method for getting rid of aspen that doesn't rely upon herbicides. The reason: in the girdled tree, upward flow of hormones, water, and nutrients continues in the intact xylem, keeping the crown alive. Thus cytokinins do not accumulate in the roots as they would in a cut tree, and a high cytokinin:auxin ratio, which would be conducive to suckering, fails to develop. In addition, the crown causes the roots to deteriorate by draining the root systems of food reserves.

Apical dominance may have a strong control over sucker regeneration; but this control is certainly not absolute. Drastic treatments are not necessary to stimulate suckering as indicated by regeneration that arises regularly in most clones, by persistent aspen invasion of grasslands, and by shoots sprouting up in lawns when aspen is planted in urban environments. This is not surprising considering the distance that auxin, a relatively unstable compound, must be transported from its source in shoots and leaves to the roots (Thimann 1977). During the long journey, there are many chances of auxin being immobilized or destroyed. The rapid breakdown of auxin at high temperatures is probably the reason that suckers arise on roots extending into exposed areas adjacent to aspen, although stimulation of cytokinin production by the same high temperatures could also be a factor (Williams 1972).

Suckering may also occur in the spring prior to bud break and translocation of auxin to the roots. Suckers will arise if soil temperatures are high enough. When the trees have flushed out, apical dominance will become reestablished.

Sucker regeneration usually is not limited by carbohydrate reserves in the roots (Schier and Zasada 1973). Repeated destruction of regeneration on cutovers by browsing, burning, or herbicide spraying, however, will exhaust carbohydrate reserves and result in dwindling numbers of suckers (Baker 1918; Sampson 1919).

Of environmental factors affecting suckering, temperature is probably the most important because of its effects on hormone balances and general metabolism (Maini and Horton 1966; Williams 1972; Zasada and Schier 1973). Light is necessary for good shoot growth after the suckers emerge above the soil surface (Farmer 1963). Aspen, a shade intolerant species, grows best in full sunlight. Availability of water doesn't appear to be an important factor limiting aspen regeneration. Water translocated upward through parent roots from deep in the soil profile enables suckers to survive even during the driest parts of the year (Gifford 1966).

Although there are a number of methods of stimulating aspen regeneration, clearcutting is the most efficient. As long as roots are plentiful and well distributed, as they are in most well-stocked stands, cutting done at any time should result in adequate regeneration. Not only does removal of all stems reduce apical dominance to a minimum, but it also enables suckers of this shade-intolerant species to grow in full sunlight.

Obtaining adequate regeneration is often a problem in deteriorating stands where death of overmature stems has reduced stocking (Schier 1975b). Natural regeneration is inhibited because residual trees maintain apical control over a shrinking root system. Generally root density has declined to such an extent that regeneration following cutting or prescribed burning will be sparse and quite patchy. Follow-up treatments, such as cutting or burning at approximately 20-year intervals, should encourage extension and suckering of roots and eventually cause unstocked areas to fill in.

Our options for managing western aspen today are limited. Lack of markets for aspen wood and a constrained budget makes it difficult for us to actively stimulate aspen regeneration.

Something, however, can be done. Natural regeneration does occur and its survival in many areas is affected by management decisions, particularly those involving livestock and wildlife. Grazing, browsing, and trampling by cattle, sheep, and big game animals seriously impede the growth and survival of aspen suckers. Regulating animal populations and controlling their distribution can contribute a great deal to the success of aspen regeneration and the perpetuation of the species in many areas.

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STAND CHARACTERISTICS OF ROCKY MOUNTAIN ASPEN

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ABSTRACT

A study is in progress at the Rocky Mountain Forest and Range Experiment Station, using data from 140 aspen stands in Colorado and southern Wyoming to describe overstory stand conditions and to characterize growth rates of aspen in the central Rocky Mountains. Differences in physiographic location, clonal characteristics, age structure, productivity, and incidence of damage and disease are being used to develop a classification scheme for making management decisions and writing silvicultural prescriptions.

The National Forests in Colorado contain an estimated 2.3 million acres of aspen (Populus tremuloides Michx.), of which 1.8 million acres are currently classified as commercial forest land. Until now, little has been known about the overstory stand characteristics of aspen throughout the Rocky Mountain region. Previous studies have either been local in nature (Morgan 1969; Severson and Thilenius 1976), or have been concerned with other factors that gave no quantitative description of the overstory (Pfister 1972; Reed 1971; Wirsing and Alexander 1975; Hoffman and Alexander 1980).

This study, based on overstory stand and growth characteristics and begun in 1979, is expected to result in a regional classification scheme for aspen in the Rocky Mountains.

Two restrictions were placed on the study: (1) existing regional inventory techniques would be used, where possible, to insure that results could be easily applied, and (2) only pure aspen, not mixed stands, would be sampled.

METHODS

Aspen stands were sampled at 140 sites, on 11 National Forests, in Colorado and southern Wyoming. Sample sites were selected to proportionally represent the typical range of stand conditions found in any given area and to include the full range of age and site classes found in the central Rockies. Existing inventory records and a preliminary reconnaissance of each forest were used to assess stand conditions and choose representative stands to sample. Both variable and fixed radius plots, similar to standard inventory plots, were randomly located within a single clone at each sample site. In stands of larger average diameter, a basal area factor was used, which resulted in 8-10 trees being sampled in each plot and usually 3 plots sampled per site. Trees 5 inches and larger were included in the sample. In smaller diameter stands, all stems were sampled using fixed radius plots, which provided 8-10 sample trees per plot. The height and diameter of each tree within the plot were measured, and ages were obtained on a representative sample of each diameter class. Radial growth for the past 10 years was also measured.

Each sample tree was examined for defects and damage. These included fork, crook, sweep, dead leader, environmental damage such as frost rack, lightning scar, and fire scar, and disease such as Cenangium or sooty bark canker and *Phellinus tremulae* trunk rot. Damage caused by animals was also recorded for each stem; these included elk gnawing, damage by rodents, and human damage.

At the center of each variable radius plot, a 1/100-acre, fixed radius plot was taken to sample stems up to 5 inches diameter at breast height (d.b.h.). Disease, damage, and poor form were also noted for these stems.

A number of clonal and overall stand characteristics were also recorded at each sample location. These included bark color--white, green, yellow, or sooty bark. Bark textures were also noted--smooth, bumpy, a characteristic swelling termed "eye knot," which adds some defect to a stem, or occasional furrowed bark. Three categories of branching characteristics of the clone were coded--live branches in the upper 1/3, the upper 1/2, or throughout the stem. Stand spacing was categorized as either uniform or clumped. Pruning was another clonal characteristic noted. Some clones prune themselves, while other clones retain many of the dead branches. Single-story, two-story, or occasionally, multistory stand structure was also coded. All of the above variables were very useful in determining clonal boundaries when sampling.

Physiographic variables such as elevation, slope, aspect, vertical and horizontal distance to the ridge-top, slope position and inclination, latitude, longitude, and yearly precipitation determined from an isohyetal map were recorded for each sample location.

The following 14 categories of aspen-associated vegetation[1] were used to identify the understory vegetation at each sample site: Aspen-Spruce-Fir, Aspen-Ponderosa Pine, Aspen-Lodgepole Pine, Aspen-Low Shrubs, Aspen-Tall Shrubs, Aspen-Shrubs-Grass, Aspen-Shrubs-Forbs, Aspen-Talus-Rockland, Aspen-Riparian, Aspen-Tall Forbs, Aspen-Thurber Fescue, Aspen-Elk Sedge, Aspen-Grass-Forbs, and Aspen-Grass.

PRELIMINARY RESULTS AND DISCUSSION

The analysis of data from this study has not yet been completed and not all variables measured have been thoroughly examined. However, a number of apparent differences and relationships have been observed.

Physiographic Differences

Stands sampled ranged from 6,900 ft to 11,000 ft in elevation, with an average of 9,300 ft. However, 96 percent of the stands sampled occurred between 8,000 and 10,800 ft.

Aspen grows on all aspects and a variety of physiographic positions in the central Rockies. Differences in growth and productivity were evident among the various locations. For example, stands on wet hillsides had larger cubic volumes than those on dry hillsides; and average site indexes (Jones 1967) of stands on dry hillsides were less than stands located in bottoms or draws, rolling terrain, or wet hillsides.

There was a marked difference between aspen stands growing on the west and east slopes of the Continental Divide. Basically, western slope stands are much more extensive, larger, more productive, and in generally better condition. About half of the eastern slope stands were in bottoms or draws, while few of the western slope stands were in these physiographic positions. Nearly one-third of the western slope stands were in rolling terrain or dry flats; none of the eastern slope stands were in those places.

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[1] Stand characteristics to meet major uses of aspen. An unpublished report by USDA Forest Service, Rocky Mountain Region, 1977.

Western slope stands had higher site indices, cubic volumes, and received more precipitation. Average diameters of western slope stands were also slightly larger, but no differences were found in average stand age, stocking, basal areas, or mean annual increments. Eastern slope stands contained more dead basal area, which could indicate somewhat poorer vigor. However, these eastern slope stands also had more suckers, indicating that they were regenerating. The lack of intensive livestock grazing on many areas of the eastern slope may be responsible for the larger number of suckers.

Differences in bark color were also noticed between eastern and western slope stands. Yellow-barked stands were much more common on the eastern slope, while green-barked stands were more common on the western slope.

There was also a marked difference in the types of understory vegetatation on either side of the Continental Divide. Grass understories predominated on the eastern slope, while grass-forb understories were most common on the western slope. Tall-shrub associations were the second most common understories on the western slope, and low-shrub associations were second in occurrence on the east slope. No tall forb associations were sampled on the eastern slope. Generally, xeric to mesic understory vegetation was common on the eastern slope while mesic to hydric or near hydric vegetation was common on the western slope. This is probably a result of the differences in precipitation between the slopes.

Quantitative Growth Variables

Average age of the stands sampled was about 80 years. The average age of mature sawlog stands (greater than 8 inches d.b.h.) was 96 years, with a range from 40 to 190 years. Stands as young as 9 years were sampled, but stands younger than 50 years are difficult to find.

Single-aged stands, in which all the stems were within 20 years of the mean age, made up most of the stands sampled. Two-aged stands, containing two distinct age classes at least 20 years apart, were second in frequency. Broad-aged stands, containing three or more age classes, made up a small portion (4 percent) of the sample. Uneven-aged stands result from some disturbance to the stand that has partially destroyed the original overstory and allowed the establishment of younger understories.

Single-aged stands had higher site indexes than two-aged stands. As could be expected, broad-aged stands had more suckers per acre in the understory than either single or two-aged stands.

Stands also had different structures. Multistoried stands had higher percentages of dead basal area than single storied stands, and they contained more suckers per acre, again indicating an ability to self-regenerate.

The distribution of stems within the stands was also related to growth characteristics. Uniformly distributed stands had a higher percentage of dead basal area than did clumpy stands. However, clumpy stands were more heavily stocked. The average site indexes of clumpy stands was somewhat higher than uniform stands, and uniform stands were older than clumpy stands, which may be related to the fact that they had a higher percentage of dead basal area.

The productivity or mean annual increment of the stands sampled varied considerably. Only 10 percent of the stands produced more than 90 ft^3/acre/year, and half of the stands produced less than 48 ft^3/acre/year. Mean annual increment was related to the basal area, site index, and stocking of a stand.

Relationship of Clonal Features to Growth

Several growth characteristics were related to clonal features. Bark color of a clone is related to growth rate and productivity. Green-barked stands had higher average site indexes and mean annual increments than yellow-barked stands. Both yellow- and green-barked stands had more stems per acre than white-barked stands, and green-barked stands were younger than white-barked stands. Yellow-barked stands contained more dead basal area and greater numbers of suckers in the understory than did green- or white-barked stands. White-barked stands had larger average stand diameter than yellow-barked stands. Finally, green-barked stands received more precipitation than either yellow- or white-barked stands.

This indicates that yellow-barked stands are an indicator of somewhat poorer productivity and stand conditions, which could prove to be a reliable, easy means of classifying relative stand conditions.

Bark texture was related to a couple of variables. Stands with bumpy bark had larger average volumes than smooth-barked stands or "eye knot" stands. Stands with furrowed bark at the base of the stems had larger average stand diameter than smooth-barked stands and were also older.

Branching characteristics were related in a number of ways to stand growth. Stands with live branches along the full length of the stem were younger, more heavily stocked, were shorter, and contained less basal area than stands with live branches on only the upper one-half or one-third of the stem. Classifying stands according to these three branching classes also resulted in differences in radial growth, cubic volumes, and average stand diameter. Basically, the relative age of a stand can be determined by the proportion of the stems that contain live branches.

Whether or not a stand is self-pruning (stems do not retain dead branches) is related to its growth characteristics. Self-pruning stands had slightly greater cubic volumes, had more dead basal area, more suckers, larger average stand diameters, and were taller and older than those that retained dead branches.

Relationship of Vegetation Associations to Growth

The vegetation associations developed by the Rocky Mountain Region aspen task force also proved useful as an indicator of relative growth. Differences in radial growth between tall shrub and low shrub types were most evident. Aspen-tall forb stands had greater cubic volumes than aspen-low shrub, aspen-grass-forb, and aspen grass stands. Site indexes and average stand diameters were higher in aspen-tall forb stands than in aspen-low shrub or aspen-grass associations.

Aspen-shrub and forb associations received more precipitation than aspen-elk sedge, aspen-grass, aspen-low shrubs, or aspen-grass-forb associations. Because aspen-tall forb associations did not receive more precipitation than other associations, ground water could be contributing to the lush, wet conditions found in these stands. Trees in the stands classified as aspen-tall forb type were taller than those in either aspen-low shrub or aspen-grass stands and had greater mean annual increments than trees in aspen-low shrub stands.

Differences in overstory growth characteristics exist among several kinds of understory vegetation. Although the data taken were not quantitative, the Rocky Mountain Region aspen vegetation associations could be useful in a classification of aspen stands.

Stem Damage

A number of factors were responsible for damage to overstory aspen stems (fig. 1). The most frequent damage was spike knot (resulting from past mortality of stem leaders); second frequent was rot. Stem wound, fork, and large-animal damage also occurred in more than half of the stands.

The main concern is the amount of damage. While spike knot occurred in most of the stands, it damaged few of the stems. Rot is not as serious as it might seem either, damaging only about one-fifth of the stems in stands where it occurred. However, rot probably has the most effect on aspen wood utilization, because a larger portion of a stem will be culled if rot is present than if other damaging agents are present.

Some agents did not occur very often but damaged considerable numbers of stems when they did occur. Fire scar occurred in only a few of the stands, but damaged about one-fourth of the stems in those stands. Small-animal damage, which occurred in a few more stands, also damaged about one-fourth of the stems, but seldom seriously affected stem vigor or product value.

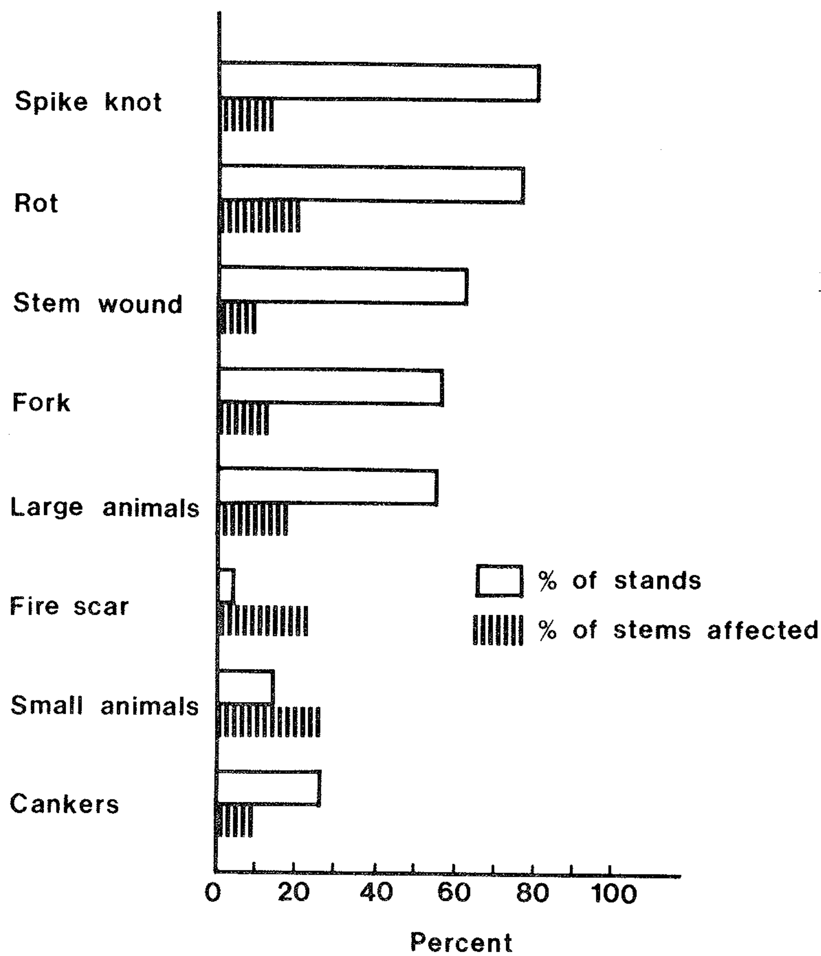

Figure 1.--Comparison of the percent of stands sampled that contained several damaging agents, and the average percent of stems damaged by those agents.

Cankers occurred in about one-fourth of the stands sampled, but usually damaged only a few of the stems in those stands. A slight increase in the incidence of infection occurred in denser stands, which logically would be expected.

Suppression occurred in about one-fourth of the stands and affected about one-fourth of the stems. It was most often present in young, dense stands and no doubt is a mechanism responsible for self-thinning in aspen. The average number of stems per acre damaged by suppression was higher than all other causes, again because suppression occurred in young, dense stands.

Fire scar and human damage occurred in open, less dense stands. In the case of fire scar, fire may have thinned the stand. In contrast, human damage is concentrated primarily around recreation areas, and these are typically placed in large diameter, open-appearing aspen stands.

Gnawing of bark by large animals damaged a considerable number of stems in some stands and can be quite serious. It is unclear why animals repeatedly damage some stands and avoid others nearby. The only relationship between large-animal damage and any of the stand characteristics measured is that heavily damaged stands had few suckers under them. Natural regeneration problems could be expected in these stands as they continue to decline under the impacts of bark gnawing of large stems and browsing of suckers.

SUMMARY

It should be possible to use the overstory characteristics discussed to develop a stand classification scheme that would adequately separate Rocky Mountain aspen stands and give the manager some silvicultural alternatives to consider in arriving at management decisions for a particular aspen stand.

For instance, if managers were interested in identifying good, healthy, fast-growing stands to manage for fiber and that would not be in immediate need of cultural treatment, they might first eliminate from consideration yellow-barked stands, two- or multistoried stands, stands with grass or low shrub understories located on dry hillsides, and stands with more than 20 percent of their stems damaged by any single agent. They would be left with stands that are healthy, good-growing, and not in need of immediate treatment.

Any number of decision models can be developed for other uses of aspen stands. This will be the next step in utilizing the large data base made available by this study

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ECOLOGICAL SUCCESSION IN ASPEN AND ITS CONSEQUENCES ON MULTIPLE USE VALUES

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ABSTRACT

Aspen can be categorized as (1) seral--successional to conifer, (2) stable--regenerates to aspen, or (3) decadent--successional to brush, forbs, or grasses. Succession to conifers reduces understory production, plant and wildlife diversity, water yields, and aesthetic values while it increases timber values. Stable aspen stands, except possibly for timber values, maintain these multiple use values if grazing is not excessive. In decadent aspen stands all of the multiple use values except water are reduced. Management expectations and returns for multiple use values would depend on the successional status of the aspen.

Aspen is the most widespread tree species on the North American continent (Fowells 1965). This feature of aspen has contributed to conflicting hypotheses about its role in plant communities. Generally, aspen is considered seral to conifers over much of its range (Baker 1918; Shirley 1941). However, aspen has also been noted for its stability in Canada (Bird 1930; Moss 1932; Lynch 1955) and the Western United States (Fetherolf 1917; Sampson 1916; Langenheim 1962). Deteriorating aspen stands have been described and compared to healthy stands in Utah (Schier 1975; Schier and Campbell 1980). Upon deterioration, an aspen stand can succeed either to conifers or to shrubs, forbs, and grasses.

Some of the incongruity about aspen succession may be due to the different successional rates made possible by various combinations of soil, site, and tree species. Lack of a conifer seed source, and the time and conditions conifers take for establishment, also mask successional rates. Gleason (1927) suggested five factors that affect successional trends: (1) reaction of vegetation to its habitat, (2) physiographic processes, (3) climatic changes, (4) immigration of new species, and (5) species evolution. Generally, the reaction of vegetation to its habitat is the factor focused on in most plant succession studies.

ASPEN SUCCESSION OVERVIEW

Harper[1] found that aspen was succeeding to conifers in 75 to 100 years on sandstone soils in central Utah. Aspen was more stable on limestone and alluvial soils, succeeding to conifers in 140 or more years. In the successional path to conifers, the grasses disappeared first, followed by forbs and then the shrubs as the conifers became established in the aspen. Understory species and yields were related inversely to the basal area coverage of the conifers. The dry matter yield of the understory dropped over one-half when conifers increased to about 20 ft^2 of basal area per acre (Harper 1973).

Kleinman (1973) examined six burned aspen-conifer sites in central Utah for the change in species related to conifer establishment. He found that density, frequency, and forage production of the understory species were influenced by grazing pressure, community age, and conifer basal area. Maximum densities of the understory species and forage production occurred about 20 years after fire. Wildlife use was influenced positively by forage production and negatively by conifer basal area and domestic livestock utilization. Warner and Harper (1972) found that the site that had the best site quality index for aspen also produced the most forage in the understory.

Many studies present evidence that water yield is increased by removing forest cover (Anderson and others 1976). Kittridge (1953) in the Sierra Nevada of California showed lower water yields under conifer stands than in open areas. From 13 to 27 percent of the seasonal snowfall was intercepted by the conifer canopy. Dunford and Niederhof (1944) studied the influence of the conifers, aspen, and open grassland types in Colorado on water yield. They found aspen and open grasslands to yield more water than conifers. Interception by the conifers was the factor that caused most of the difference. Jaynes (1978), in a

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[1]Differential successional rates in aspen forests of central Utah, by K. T. Harper, 1973, unpublished report in files at Forestry Sciences Laboratory, Logan, Utah.

watershed hydrology model in Utah, predicted 4.6 inches net loss in water yields when aspen converts to conifers, and 3.4 inches net loss when grass-forb converts to aspen. His model suggested that conifer invasion of aspen reduced streamflow as the result of differing snowmelt and plant activity patterns.

IMPACT OF SUCCESSION ON MULTIPLE USE VALUES SOME GENERAL HYPOTHESES

I have hypothesized successional curves for the multiple use values of water, timber, forage, wildlife, and recreation. These curves result from a review of literature, from discussion and work with colleagues (see Bartos 1973; DeByle 1976; Mueggler 1976), and from my personal observations. The curves are scaled from 1 to 10 for the multiple use values and begin in year zero after some major disturbance to the tree overstory. Two curves are presented, one for succession after burning, and one for succession after cutting or spraying.

To present plant succession in western aspen, I have divided the aspen forest into three broad categories; (1) decadent, (2) stable, and (3) seral aspen. Decadent aspen is characterized by low levels of aspen stocking, high stem mortality, little sucker regeneration, and with no replacement by conifers. Ultimately it will succeed to brush, forbs, or grasses. Stable aspen is characterized by high levels of aspen stocking, no unusual mortality, no or few conifers, and shows evidence of regeneration through more than one generation of aspen stems (that is, †125 years). Seral aspen is characterized by high levels of aspen stocking after a disturbance, with conifers significantly increasing aspen mortality and reducing aspen regeneration in one generation of aspen stems (that is, within 50-120 years aspen will begin to turn over to conifers).

After burning, water yields would be the highest at the beginning of succession because little vegetation exists in all three aspen situations (fig. 1). As aspen mature and transpire more water, there would be a decrease in water yields. In decadent aspen stands, with the demise of aspen, water yields should slightly increase late in stand succession. In stable aspen stands, as the aspen trees mature, water yields would decline and then stabilize. As conifers come in and occupy seral aspen stands, water yields would decline, primarily through losses from interception. When a mature conifer stand occupies the site, water yields would stabilize at a lower level. Cut or sprayed aspen stands would have lower water yields than burned stands because of water use by the understory vegetation that remained after treatment. Later in succession, after the aspen begin to mature, the successional patterns of burning, cutting, or spraying should mimic each other.

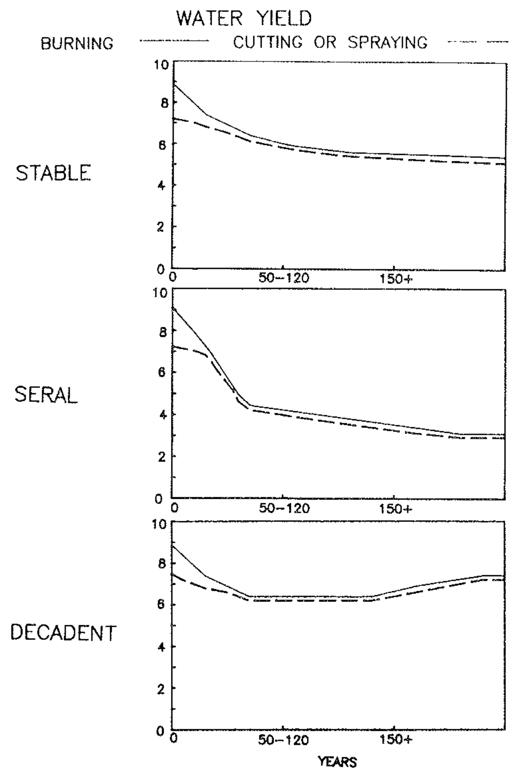

Figure 1.

In terms of volume, timber should increase as succession advances in decadent, stable, or seral aspen stands (fig. 2). Volume would be low in the decadent stand and would decline with the demise of the aspen trees. The decadent stands generally have a ratty appearance caused by branchy, crooked stems (Schier and Campbell 1980). They also found site index, tree height, basal area, number of stems, and bole length to be lower in decadent aspen stands when compared with healthy, stable aspen stands. Tree volume in stable aspen stands would increase until stand maturity; then, as the aspen trees become overmature and the stand deteriorates, waves of reproduction would come in. At this time, timber volume would decrease slightly and stabilize as an even-aged group or all-aged aspen stand develops. With the addition of conifer in the seral stand, tree volumes would increase until the aspen begin to disappear, then level off or decline as succession proceeds. Disease in the aspen would reduce the value of the aspen for timber products as succession continues to conifers. Cutting the aspen when it matures would minimize the disease loss.

Timber responses after burning, cutting, or spraying are assumed to be nearly similar. This assumption ignores the strong delaying effect that understory vegetation can have on tree reproduction and subsequently on timber volumes. Burning, by removing the understory vegetation, may prepare a better seedbed for trees to reproduce. In certain situations, for instance with thick stands of brush, removal of the understory vegetation should be considered after spraying or cutting aspen stands.

After burning, forage production would increase rapidly as the herbaceous vegetation, shrubs, and aspen suckers regenerate and grow (fig. 3). As the aspen mature, and suckering declines, forage production would decline slightly and level off in both the decadent and stable aspen stands. In seral aspen stands, forage production would continue to decline as the conifers mature and take over the stand. Also, the number of plant species would decrease and change to more shade tolerant plants as conifers occupy the sites. Cutting or spraying would not affect forage production to the degree that burning would, and thus production would be higher in early succession. As succession proceeds, and aspen matures, there would be little difference in treatments on forage production.

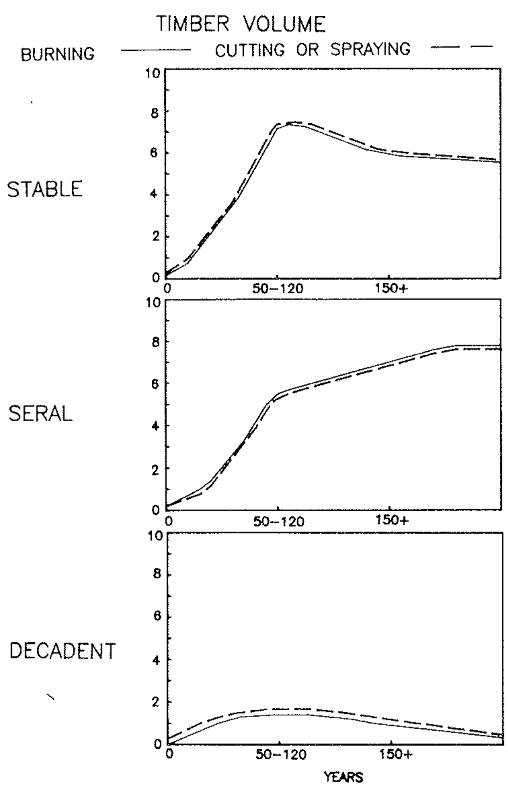

Figure 2.

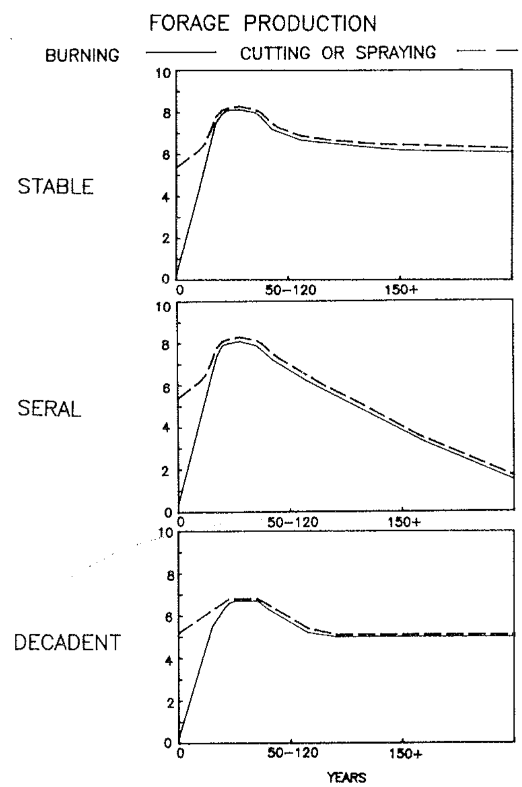

Figure 3.

Wildlife habitat and diversity or number of animal species would increase early in succession (fig. 4). Cutting or spraying an aspen stand would not reduce habitat or diversity as much as burning in the early years after treatment. With the demise of aspen, wildlife habitat and diversity would tend to decrease in decadent aspen stands. Wildlife values should stabilize at a high level in stable aspen stands as the aspen mature and later become overmature and break up. In seral stands, a good mix of aspen and conifer should give optimum habitat and diversity for wildlife. As the aspen die out of the seral stand, both wildlife habitat and diversity would decrease.

Recreation values would generally be low in decadent aspen stands because of the ratty appearance and high incidence of disease (fig. 5). The recreational value in stable aspen stands would increase as succession proceeds and stabilize at a high level because of the diverse wildlife, forage, and scenic qualities of these stands. In seral stands, an aesthetically pleasing mix of aspen and conifers should give maximum recreational values for many years. As the aspen die out and conifers occupy the site, recreational values would decline. Cutting or spraying would have less impact on recreational values than would burning only in the early years after treatment.

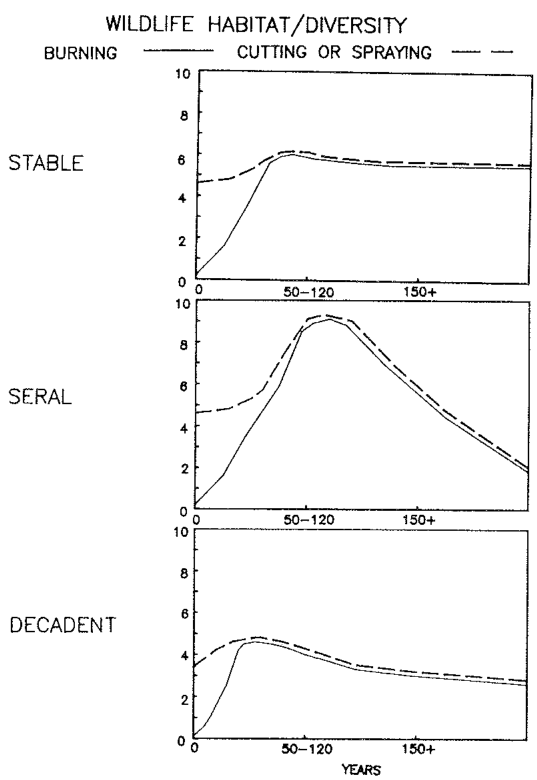

Figure 4.

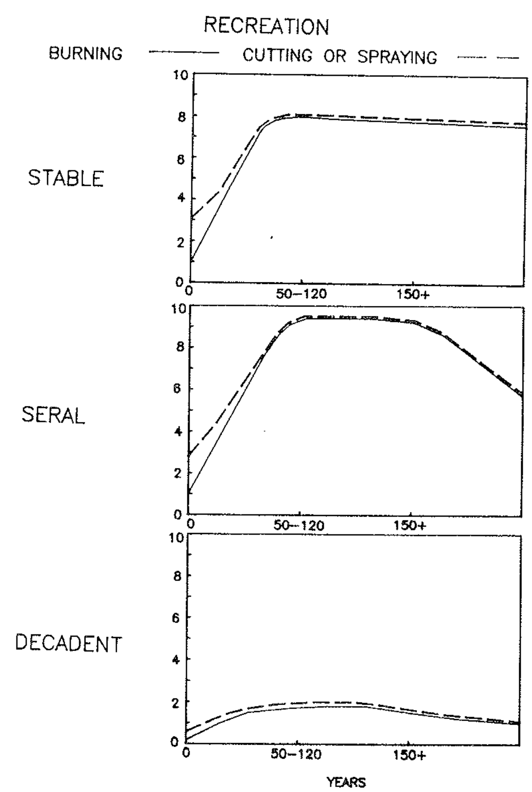

Figure 5.

Some conclusions about the effects of aspen succession on management decisions would be:

1. Management expectations for water, timber, forage, wildlife, and recreation values would be dependent on the successional status of aspen--that is, whether the aspen is decadent, stable, or seral.

2. Decadent aspen stands, in terms of management returns, have low expectations; conversely, seral aspen stands have high expectations for management returns.

3. Water, forage, wildlife, and recreational values diminish rapidly as succession proceeds to conifers.

4. On marginal sites for timber production, control of conifers in seral aspen stands would increase or maintain water, forage, wildlife, and recreational values.

5. On sites where aspen timber and other resource values are marginal or secondary, and where conifer timber growth and value are very high, succession would be more rapid by converting seral aspen stands to conifers.

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ASPEN COMMUNITY TYPE CLASSIFICATIONS
IN THE INTERMOUNTAIN WEST

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ABSTRACT

Resource managers need to recognize differences in site potential, successional status, and trends for aspen-dominated wildlands. A community type classification approach is suggested as the most appropriate. This classification describes the current vegetation and associated environmental factors, and portrays hypothesized successional trends. Examples of applying the classification to various resource management situations on the Bridger-Teton National Forest are provided. Situations include wildlife habitat improvement for big game and cavity-nesting birds; management for community diversity, watershed protection, and forage production; information for resource planning; and for study of fire effects.

Aspen (Populus tremuloides Michx.) is the most widely distributed tree in North America. Throughout the Intermountain West, aspen expresses great ecological amplitude. It is found growing under a wide variety of environmental conditions including broad differences in slope, aspect, elevation, soils, and climate. Aspen is also found in different successional stages, such as a fire-induced seral component of a conifer climax or grass-shrub sere (Krebill 1972; Schier 1975), or as a stable or de facto climax component in an aspen climax sere (Mueggler 1976). Differences in site (environment) and succession result in considerable variation in the composition and productivity of associated species.

Resource managers have recognized the importance of aspen as a visual resource, as key areas of wildlife habitat and forage production, in watershed protection, and in fire management (Hronek 1976). Intensive multiple use management of these wildland resources requires that the variability in aspen sites be partitioned into natural units according to their potential productivity and probable response to management. This paper describes and compares various techniques of stratification, and selects one method (community types) for application in several resource management situations on the Bridger-Teton National Forest in western Wyoming. Application includes input for wildlife habitat improvement projects for big game and cavity-dependent wildlife; determination of successional trends and community diversity; management for watershed protection, land stability, and forage production for domestic livestock; resource mapping and long-range planning, and study design and layout for fire effects investigations.

CLASSIFICATION

Classification is the systematic ordering or arranging of objects into sets on the basis of similarities or relationships (Bailey and others 1978; Pfister 1977). This process results in a classification system with which additional objects then may be identified. The principal benefit of a classification system is that inductive generalizations can be made for the classes or sets that are constructed (Gilmour 1951; Whittaker 1975; Kressell 1979).

Prior to the 1970's, site or resource classifications for the aspen-dominated lands in the Intermountain West were developed for a single purpose or function. The Society of American Foresters' (SAF) (1954, 1980) aspen cover type is based solely upon the current dominance (at least 80 percent of basal area) of aspen within a stand. It encompasses a wide range of environmental conditions and successional trends. Only limited generalizations can be made for any given site's potential to produce multiple resource values.

Range environmental analysis for the Intermountain Region of the Forest Service recognizes three groups or types of aspen stands based upon undergrowth vegetation: climax or permanent aspen, transition or disclimax aspen, and ecotonal aspen (FSH 2209.21).[1] Even though differences on successional status are indicated, the actual process for identifying these differences is not provided. Wide ranges of productivity exist within these types, making them little better for resource value prediction than the single SAF cover type.

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[1] Range Environmental Analysis Handbook, Forest Service Directives System.

More recent work in resource classification has centered around the habitat type concept (Daubenmire and Daubenmire 1968; Pfister and others 1977; Steele and others 1979). This approach to development of a site classification uses vegetation as an indicator of similarity within units of the environment. Daubenmire recognized the need to maintain a constant factor of time (succession) in order to classify sites (environments) and their respective potential features (Daubenmire 1952; Pfister 1977). The resulting classified sets then became habitat types, or aggregations of all units of land potentially capable of supporting similar plant communities at climax. Habitat types are identified by vegetation, with the assumption that the vegetation integrates more of the interacting environmental characteristics than do more of the interacting environmental characteristics than do single factors such as soils or climate. Individual units of land belonging to a single habitat type can be expected to react similarly to perturbations and to have similar productivities. Management considerations for each unit of land would then be similar. Forest communities used to develop habitat type classifications for each unit of land would then be similar. Forest communities used to develop habitat type classification were selected to reflect mature, near-climax conditions in balance with the abiotic environment (Steele and others 1979). Communities that were obviously seral, or still changing with time, were ignored in sampling these areas.

Several recent studies throughout the Intermountain West have recognized different aspen habitat types. Kerr and Henderson (1979) and Henderson and others (1977b) describe aspen habitat types from the Manti-LaSal National Forest in central Utah. The Uinta Range of northern Utah contains two additional types (Henderson and others 1977a). A shrub-dominated sites to wet, fern-dominated sites (Hoffman and Alexander 1980). This conditions necessary for habitat type status, and includes aspen communities that contain plant species indicative of site deterioration. In Wyoming, several aspen habitat types have been described for the Black Hills and Bear Lodge Mountains (Severson and Thilenius 1976), the Medicine Bow National Forest (Wirsing and Alexander 1975), and the Big Horn Mountains (Hoffman and Alexander 1976). A single, broadly defined aspen habitat type, indicated by the presence of Symphoricarpos oreophilus, has been described for the Wind River Mountains by Reed (1971).

The habitat type classification developed for western Wyoming by Steele and others (1979) is intentionally inapplicable in aspen communities. Undergrowth species composition in aspen communities usually bear little or no resemblence to mature or old-growth conifer-dominated communities. Resource managers on the Bridger-Teton were left with making management decisions concerning aspen communities for which there was not an adequate classification.

COMMUNITY TYPE CLASSIFICATION

Two contrasting philosophies have developed to explain plant community distribution. Advocates of the continuum theory originated by Gleason (1926) emphasize the independent response of plant species to environmental pressures (Curtis 1959; McIntosh 1967; Whittaker 1975). Plant species or communities are displayed as being ordinated along some gradient. In contrast, the typical association theory emphasizes that plant species or distinct communities occur across the landscape in response to similar habitats or environments (Daubenmire and Daubenmire 1968; Pfister and others 1977; Henderson and West 1977; Steele and others 1979). Regardless of the theory currently in vogue, resource managers still need an aspen classification based upon vegetation. As Whittaker (1975) explains, there is no real conflict between these opposing viewpoints when classification is used as a basis for communication.

The community type approach to classification, like habitat types, is aimed at identifying and classifying units of the resource that are sufficiently homogeneous at different levels of generalizations to permit meaningful biological and managerial predictions. Both are hierarchical in development. Community types represent aggregations of all units of current vegetation (stands or communities rather than units of land) based upon floristic and structural similarities.

Development of a community type classification for aspen-dominated wildlands usually follows a pattern similar to that used in habitat type classifications. The key difference is that actual or current vegetation is used as the basis, regardless of successional stages, site disturbance, or deterioration. Henderson and West (1977) present a detailed methodology for fieldwork. Aspen communities are sampled, using a "subjectively without preconceived bias" plot selection (Mueller-Dombois and Ellenberg 1974). An attempt is made to examine the full range of environmental conditions in which aspen occurs. Data collected includes plant species composition, cover, and production; tree stem densities, heights, and ages; and environmental features such as elevation, aspect, slope, configuration, juxtaposition to surrounding communities, and apparent successional status and trends (Youngblood 1979; Kerr and Henderson 1979; Mueggler and Campbell, in press).

Analysis of field data employs a number of grouping techniques. The goal of each is to arrange the sample stands or communities into groups of maximum within-type similarity and minimum between-type similarity (Henderson and West 1977). No assumption is made about the "natural" or "artificial" nature of the resulting groups or community types, although natural groupings are certainly desirable.

Several numerical techniques represent somewhat objective attempts at classification. Canopy coverages of individual plant species provide the basic data in each of these. Mathematical similarities between sample plots are computed by numerous indices of similarity, resulting in a similarity matrix. Commonly used indices, such as Sorenson's K (Dick-Peddie and Moir 1970; Dyrness and Franklin 1974; Kerr and Henderson 1979; Younglood 1979) and Sorenson's community coefficient (Mueggler and Campbell, in press; Henderson and West 1977) are explained by Mueller-Domboise and Ellenberg (1974) and Marshall and Romesberg (1977). Cluster analysis (Sokal and Sneath 1963) displays the relationship between sample plots by producing a dendogram. A final numerical technique is that of ordination, in which the individual sample plots are displayed as existing in two-dimensional space, at a relative distance from reference stands at the ends of each axis (Lawton 1979; Pfister and Arno 1980).

These numerical taxonomic techniques permit a somewhat objective view of the environmental relationships responsible for species composition and distribution. Classifications relying soley upon combinations of these techniques, however, are usually inadequate when applied to existing resources. Numerical techniques fail to recognize the few species or vegetative unions that might have indicator value for some environmental condition. Problems arise when species of high overall constancy, regardless of site characteristics, or the extreme variation in presence and cover of relatively minor species, nullify the presence of more restrictive species (Youngblood 1979; Mueggler and Campbell, in press).

A more subjective approach to classification utilizes the association or synthesis table method (Mueller-Domboise and Ellenberg 1974). This technique allows the ecologist to recognize the presence of floristic similarities through fidelity, constancy, and coverage. Subsequent regroupings emphasize those species exerting a dominant role in the community and those indicative of previous disturbance.

A combination of objective and subjective approaches produces the most meaningful and useful classification. Each method is applied independently and then compared for similarity. Disagreements in grouping between methods requires modification of the groups or additional analysis. Following the final grouping of sample plots into types, the groups are named based upon the diagnostic overstory and undergrowth species present. Finally, a dichotomous key is developed for field identification of community types. Individual community types are described in terms of environmental parameters, associated vegetation and structure, surrounding plant communities, management implications, and relationship to previously described types. The classification is usually hierarchical in that similar types may be grouped at higher levels corresponding to cover types.

Several recent studies have recognized aspen community types in the Intermountain West, including the north slope of the Uinta Mountains (Winn 1976), the Manti-LaSal National Forest (Kerr and Henderson 1979; Henderson and others 1977b), the Bridger-Teton National Forest (Youngblood 1979; Youngblood and Mueggler 1981), and the Caribou and Targhee National Forest (Mueggler and Campbell, in press).

APPLICATION

The validity of any classification can be determined only through its application in resource management. The community type then becomes the basic unit for determining resource values and management policy. It may be used singly, or several types having a similar resource value and probable response to management activities may be combined into a larger analysis group.

The aspen community type classification for the Bridger-Teton National Forest (Youngblood 1979; Youngblood and Mueggler 1981) is being used in this manner. This classification describes 26 community types, belonging to three cover type groups. The following is a brief description of several ways in which this classification is being applied.

Succession

The 26 aspen community types describe current vegetation. Successional status and trend, however, is a key consideration because it plays a major role in management decisions. Seventeen of these types have the potential for developing into nine different climax communities dominated by conifers as described by the habitat type classification of Steele and others (1979). Nine aspen community types represent apparently stable conditions. These relationships are displayed in table 1.

Due to the current effort in Forest planning, the aspen resource has received increased attention, especially to provide for overall diversity of stand structure. The ability to describe successional trends within the aspen resource was a critical prerequisite. Stand structure and composition of each community type was evaluated to determine a mean rate of succession. Community types were then grouped into the three following classes:

Populus tremuloides - *Abies lasiocarpa*/*Prunus virginiana* c.t.	*Abies lasiocarpa*/*Berberis repens* c.c.t.
Populus tremuloides - *Abies lasiocarpa*/*Ligusticum filicinum* c.t.	*Abies lasiocarpa*/*Arnica cordifolia* c.c.t.
	Abies lasiocarpa/*Ribes montigenum* c.c.t.
Populus tremuloides - *Abies lasiocarpa*/*Pedicularis racemosa* c.t.	*Abies lasiocarpa*/*Pedicularis racemosa* c.c.t.
Populus tremuloides - *Abies lasiocarpa*/*Berberis repens* c.t.	*Abies lasiocarpa*/*Berberis repens* c.c.t.
Populus tremuloides - *Abies lasiocarpa*/*Shepherdia canadensis* c.t.	*Abies lasiocarpa*/*Arnica cordifolia* c.c.t.
Populus tremuloides - *Abies lasiocarpa*/*Arnica cordifolia* c.t.	*Abies lasiocarpa*/*Arnica cordifolia* c.c.t.
Populus tremuloides - *Abies lasiocarpa*/*Rudbeckia occidentalis* c.t.	Uncertain
Populus tremuloides - *Pseudotsuga menziesii*/*Spiraea betulifolia* c.t.	*Pseudotsuga menziesii*/*Spiraea betulifolia* c.c.t.
	Pseudotsuga menziesii/*Symphoricarpos albus* c.c.t.
Populus tremuloides - *Pseudotsuga menziesii*/*Calamagrostis rubescens* c.t.	*Pseudotsuga menziesii*/*Calamagrostis rubescens* c.c.t.
Populus tremuloides/*Ranunculus alismaefolius* c.t.	Stable[1/]
Populus tremuloides/*Equisetum arvense* c.t.	*Picea*/*Equisetum arvense* c.c.t.
Populus tremuloides/*Heracleum lanagum* c.t.	Stable[1/]
Populus tremuloides/*Prunus virginiana* c.t.	*Pseudotsuga menziesii*/*Berberis repens* c.c.t.
Populus tremuloides/*Ligusticum filicinum* c.t.	*Populus tremuloides* - *Abies lasiocarpa*/*Ligusticum filicinum* c.t.[2/]
Populus tremuloides/*Spiraea betulifolia* c.t.	*Populus tremuloides* - *Pseudotsuga menziesii*/*Spiraea betulifoila* c.t.[2/]
Populus tremuloides/*Calamagrostis rubescens* c.t.	Stable
	Abies lasiocarpa/*Calamagrostis rubescens* c.t.
	Populus tremuloides - *Pseudotsuga menziesii*/*Calamagrostis rubescens* c.t.[2/]
Populus tremuloides/*Juniperus communis* c.t.	Stable[1/]
Populus tremuloides/*Berberis repens* c.t.	*Populus tremuloides* - *Abies lasiocarpa*/*Berberis repens* c.t.[2/]
Populus tremuloides/*Shepherdia canadensis* c.t.	*Populus tremuloides* - *Abies lasiocarpa*/*Shepherdia canadensis* c.t.[2/]
Populus tremuloides/*Arnica cordifolia* c.t.	*Populus tremuloides* - *Abies lasiocarpa*/*Arnica cordifolia* c.t.[2/]
Populus tremuloides/*Astragalus miser* c.t.	Stable[1/]
Populus tremuloides/*Thalictrum fendleri* c.t.	Stable[1/]
Populus tremuloides/*Rudbeckia occidentalis* c.t.	*Populus tremuloides* - *Abies lasiocarpa*/*Rudbeckia occidentalis* c.t.[2/]
Populus tremuloides/*Artemisia tridentata* c.t.	Stable
Populus tremuloides/*Symphoricarpos oreophilus* c.t.	Stable
Populus tremuloides/*Wyethia amplexcaulis* c.t.	Stable[1/]

[1/]Stability questionable

[2/]Intermediate seral stage, described above

Table 1.--Probable sucessional trends relating aspen community type (c.t.) to either stable communities or climax community types (c.c.t.) dominated by conifers, as described by Steele and others (1979).

STABLE: Those community types appearing stable and self-reproducing and being devoid of conifer invasion

SLOW: Those community types requiring at least 70 years to achieve significant conifer invasion

FAST: Those community types in which significant conifer invasion occurs within the first 70 years of stand development

These classes then were used as stand descriptors in the mapping phase of the planning effort. If maintaining diverse age classes and stand conditions in aspen across the landscape is selected as a management objective, this grouping will provide the framework for implementation. Then primary consideration for project scheduling can be given to those sites that have the highest probability of being replaced by conifers in the immediate future.

Land Stability

A *Populus tremuloides/Heracleum lanatum* community type has been identified as occurring on soils with high available waterholding capacities. Usually this type occurs on flat benches above riparian areas, on toeslopes or avalanche chutes, or along side slopes with perrennial springs and seeps. The slopes are usually unstable and occasionally slump. This presents a problem for road location and maintenance. Identification of this community type in the field has proved beneficial by providing a basis for route selection and for specific revegetation procedures following site disturbance.

Range and Wildlife Habitat

Application of the community type classification potentially has the highest benefit for range and wildlife habitat improvement. Managers have a basis for describing and communicating ideas pertaining to existing conditions. Aspen sites that have received intensive disturbance from domestic livestock are described by the *Populus tremuloides/Rudbeckia occidentalis* and *P. tremuloides/Wyethia amplexicaulis* community types. Other sites with negligible disturbance are described by the *P. tremuloides/Heracleum lanatum* and *P. tremuloides/Ligusticum filicinum* community types.

Elk spring and fall range in the Gros Ventre River drainage of the Bridger-Teton National Forest is a complex mosaic of aspen stands, open sagebrush steppe, and coniferous forest. A majority of the timbered area above 8,000 ft belongs to the *Abies lasiocarpa/Arnica cordifolia* habitat type (Steele and others 1979). Aspen is a dominant seral component of this habitat type, and comprises several different community types within this drainage. The relative importance of aspen communities for spring and fall range can be evaluated by examining the relative abundance of those undergrowth species having food value for elk.[2] There is a two-to-four fold decrease in relative forage value for elk as succession proceeds from a pure aspen community to a subalpine fir community (fig. 1). Below 8,000 ft, the *Abies lasiocarpa/Calamagrostis rubescens* and *Pseudotsuga menziesii/Calamagrostis rubescens* habitat types become more dominant with aspen being an important seral species. Aspen communities in an early seral condition provide about 50 percent more forage value than the climax conifer-dominated communities (fig. 2). In addition, aspen can be important browse for elk during the winter and early spring seasons.

The importance of aspen to bird communities, especially cavity-nesting species, is well-documented (Thomas 1979; Winternitz 1980; Young 1977). The effectiveness of maintaining a desired number of standing dead snags of suitable size classes in areas that receive stand regeneration treatments is currently being evaluated using the aspen community type classification. Wildlife biologists can determine the potential for snag production for any given aspen stand using the following indices:

1. Current stand condition, expressed as stand age and number of stems per acre by diameter class.

2. Predicted stand structure for a specific community type (table 2).

3. Respective growth curve showing the time required to produce a given diameter (fig. 3).

Using this approach, four aspen community types appear to have the potential for producing snags of at least 12 inches diameter at breast height (d.b.h.). Three additional aspen community types appear to have the potential for producing snags with a 6-inch maximum d.b.h. Management of aspen for snag-dependent species that require snags of a given size can only occur on sites with the potential for providing trees of this size.

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[2]Average food value for elk ratings, derived from published literature calculated for 103 plant species. Data on file, Bridger-Teton National Forest.

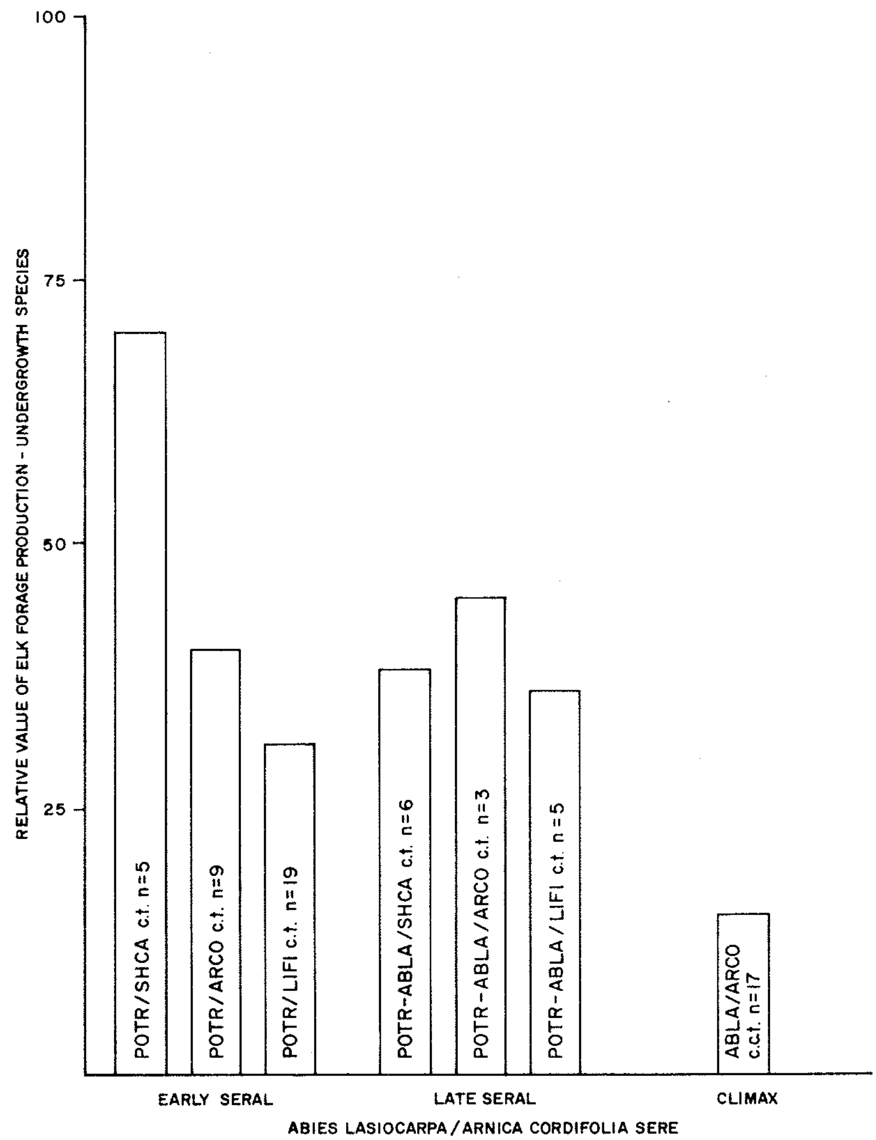

Figure 1.--Relative value of elk forage production by different successional stages in the Abies lasiocarpa/Arnica cordifolia habitat type (c.t. = community type, c.c.t. = climax community type.)

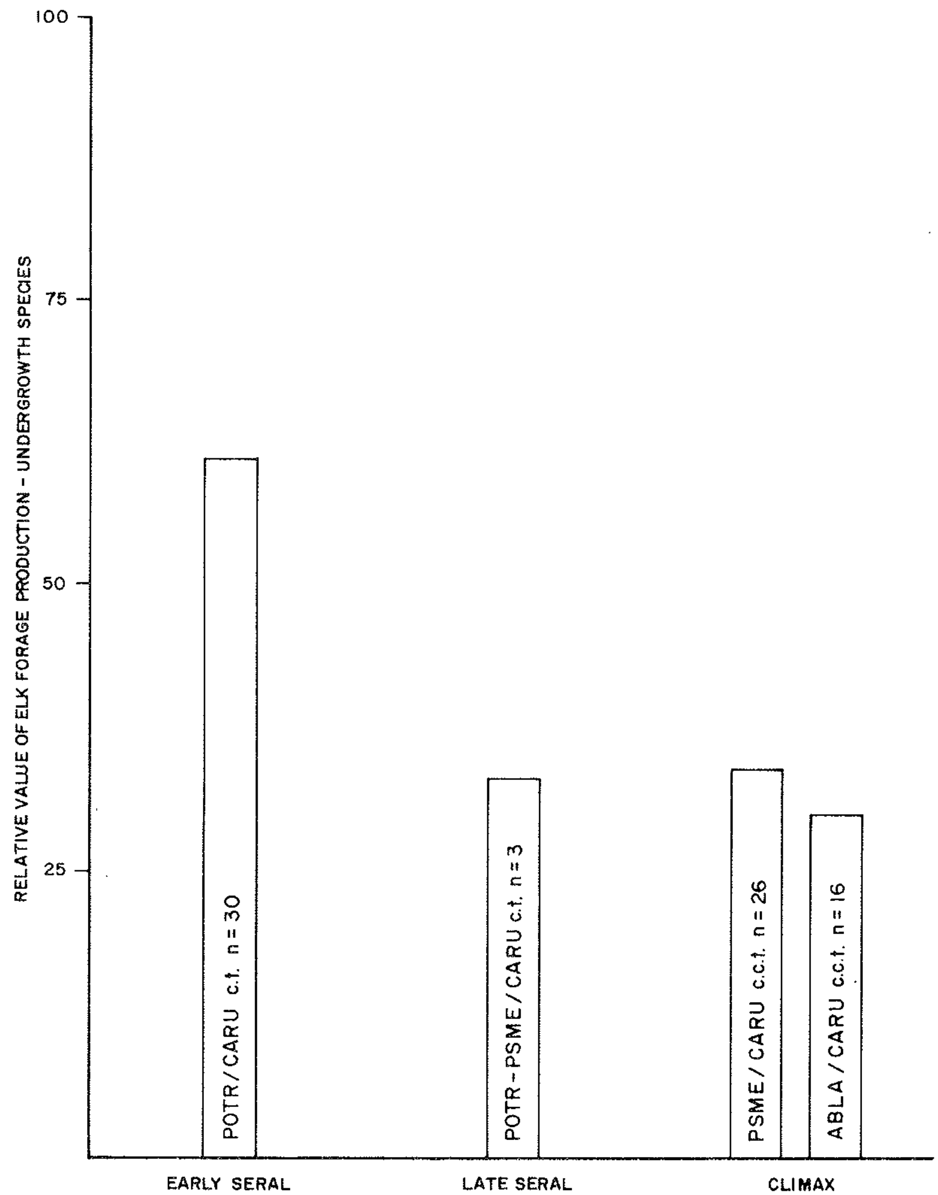

Figure 2.--Relative value of elk forage production by different successional stages in the *Pseudotsuga menziesii/Calamagrostis rubescens* and *Abies lasiocarpa/Calamagrostis rubescens* habitat types (community type = c.t., climax community type = c.c.t.).

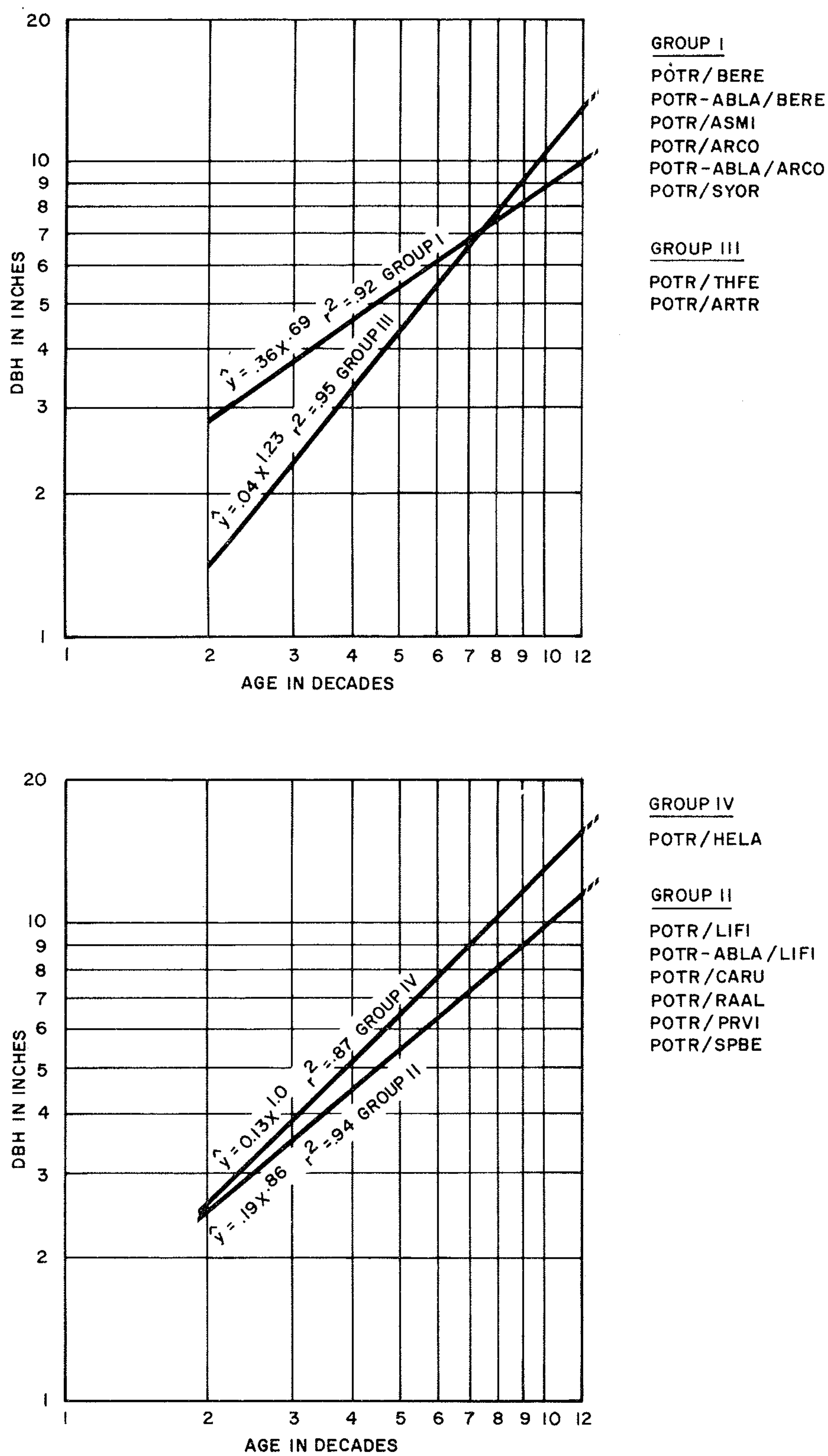

Figure 3.--Diameter growth by decade for aspen community types on the Bridger-Teton National Forest.

Table 2.--Predicted stand structure by community type

	Community Type	Mean Age[1]	Number of Stems Per Acre Specific DBH (inches)[2] 6	10	12
Group I	Potr/Bere	72 ± 19	139		
	Potr - Abla/Bere	77 ± 19	121	17	
	Potr/Asmi	94 ± 22	327	30	
	Potr/Arco	70 ± 13	117	18	12
	Potr - Abla/Arco	88 ± ?	196	16	
	Potr/Syor	91 ± 34	180	11	
Group II	Potr/Lifi	96 ± 13	173	32	12
	Potr - Abla/Lifi	100 ± 18	212	22	
	Potr/Caru	85 ± 8	152	24	
	Potr/Raal	120 ± ?	200	70	27
	Potr/Prvi	79 ± 16	143		
	Potr/Spbe	81 ± 19	195	17	
Group III	Potr/Thfe	76 ± 9	187	17	
	Potr/Artr	74 ± ?	72		
Group IV	Potr/Hela	106 ± 34	234	88	40

1/ Confidence limits (95 percent) for estimating the mean age are given where n = 5 or more.

2/ Stand table indicates diameter classes with at least 10 stems per acre.

Fire Effects

The effect of fire in the aspen ecosystem serves as another example of application of community type classification to resource management situations. The Bridger-Teton National Forest is currently engaged in returning fire by prescribed burning to this fire-dependent ecosystem. The fires are intended to benefit wildlife and domestic livestock by regenerating aspen, removing competition from conifers, and stimulating the production of browse and forage. The aspen community types provide a basis for comparison of techniques and results. Because of the similarity in environmental characteristics and species composition among sites belonging to the same community type, fire behavior and fire effects should also be similar within a community type.

CONCLUSIONS

Aspen is an important resource in the Intermountain West and is found on a wide variety of sites. Aspen may be replaced by conifers, by shrubs, or may maintain itself. Its successional status is dependent upon the site. Undergrowth species associated with aspen vary with both site and successional stage, resulting in a wide range of productivity. Resource managers have recognized the complexity of the aspen ecosystem, and have applied several classifications to assist in making logical generalizations for improved management. A community type classification appears to be most appropriate in aspen because of the difficulty in determining potential climax conditions. Community type classification describes current conditions; these are most important to resource managers. It serves as a tool with which resource managers can communicate ideas concerning the aspen resource. The classification provides a basis for hypothesizing the pathways leading to climax conditions. This link to the habitat type classification allows for comparison of different conditions that potentially occur on the same unit of land.

The aspen community type classification, developed for the Bridger-Teton National Forest, has several direct applications. It provides a logical framework for the communication of ideas and the interpretation and application of results. It is being used in a Forest-wide multiple use planning process to describe the different successional trends that occur within the aspen ecosystem. Once mapped, sites belonging to different successional pathways will have different and specific management strategies developed and applied. A single community type is used to indicate areas of unstable soil. Other types indicate areas of intense disturbance from domestic livestock. The classification provides a means for determining optimum stand conditions for wildlife and domestic livestock. Forage production, development of suitable trees for cavity-nesting birds, and the effectiveness of prescribed fire vary by community type.

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ASPEN HARVEST ON THE SAN JUAN NATIONAL FOREST:

VOLUMES, SILVICULTURAL METHODS, AND RESULTS

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ABSTRACT

Aspen occurs as a forest type on the San Juan National Forest and is an important component of the Englemann spruce/subalpine fir and the Douglas-fir/white fir types. Aspen has been harvested commercially for many years on the Forest. Results of aspen harvesting differ for three situations: (1) where aspen is a mature part of a coniferous overstory; (2) where aspen is an overstory with a fully stocked coniferous understory; and (3) where aspen is a pure stand with no coniferous mixture. Effects of grazing, residues, and cutting intensity are provided.

The San Juan National Forest in Southwestern Colorado encompasses about 2 million acres of which 1,850,000 acres are National Forest land. Elevations range from 6,500 ft to over 14,000 ft. Its climate is characterized by low relative humidities, abundant sunshine, cool summers with frequent thunder storms, heavy winter snow, and wide daily temperature fluctuations. Annual precipitation varies from 15 to 60 inches with about 65 percent occurring as snow. Prevailing winds are from the southwest, bringing most of the large storms into the area from off the southern California coast. Most soils on the Forest have developed from sandstones, limestones, and shales, and are very productive.

The Forest contains four commercial timber types: the ponderosa pine, Douglas-fir/white fir, spruce-fir, and aspen (table 1). These types range in elevation from 6,500 ft to 10,500 ft.

Aspen is found throughout a wide elevation band and on a variety of soils. It often forms the lower forest boundary, abutting vegetation types characteristic of lower elevations. It grows as islands in the spruce-fir type, and occasionally as a sprawling shrub at timber line. It is a short-lived species that appears after forest fires, and normally will be replaced by conifers through secondary plant succession. The aspen type on the San Juan National Forest is largely the result of wildfires that burned off the conifers.

Table 1 -- Area of commercial forest land and aspen volume in sawtimber stands, by forest type, on the San Juan National Forest

Forest Type	Area of commercial forest land	Area of sawtimber stands	Cu.ft. in sawtimber stands	Board feet (Scribner)	Board feet (Scribner)
	Acres	Acres	Thousands	Thousands	Per Acre
Spruce-fir	421,021	383,900	64,470	226,514	590
Ponderosa pine	342,548	191,000	1,888	0	0
Douglas-fir--white fir	231,529	195,600	43,933	111,479	570
Aspen	268,864	66,500	108,301	337,600	5,076
	1,263,962	837,000	218,592	675,593	

Aspen is recognized as a commercial sawtimber species. The demand for aspen sawtimber from the Forest has been increasing. Aspen sawtimber represented only 5 percent of the total volume cut on the Forest in 1970. It represented 8 percent in 1975, and it increased to 15 percent in 1980 (table 2). During each of the past 5 years, the San Juan has harvested an average of 5,100 MBF (thousand board feet) of aspen sawtimber. Aspen is manufactured locally into matchsticks, excelsior, shingles, decking, lumber, studs, and interior panelling. Prices bid for aspen sawtimber have increased from about $1.00/MBF in 1976 to an average of about $15.00 in 1981. Recent sales have been bid up to as high as $50.00 per MBF. There are only minor markets for aspen less than sawtimber size; these are primarily for dead trees to be used as uranium mine props. Our utilization standards are basically the same as for conifers: minimum of 7 inches diameter at breast height (d.b.h.), 6-inch top diameter, and at least one-third sound. Our aspen sawtimber sales have ranged in size from 500 MBF to 7,000 MBF.

The commercial aspen type occurs on 269,000 acres or 21 percent of the commercial forest land on the San Juan National Forest. Within the aspen type, associated softwoods make up approximately 20 percent of the total cubic foot volume. Of the 269,000 acres of aspen type, 66,500 acres or 25 percent are classed as sawtimber, 119,000 acres or 44 percent are classed as poletimber, and 85,500 acres or 31 percent are seedling-sapling or nonstocked. Stand age data show that many stands reach rotation age without growing to sawtimber size. A rotation of 80 to 100 years in the Rocky Mountains has been recommended. We have 89,500 acres over 100 years old (table 3). For this to be, at least 23,000 acres of poletimber must be over rotation age. Our aspen sawtimber stands average about 5 MBF per acre net volume and run as high as 20 MBF per acre.

Table 2 -- Board foot (Scribner) volume of aspen cut and percent of total Forest cut in the past 15 years.

Year	MBF cut	% of forest harvest
1966	6,692	7.5
1967	3,440	3.7
1968	2,489	2.4
1969	4,219	5.5
1970	3,913	5.5
1971	3,452	4.8
1972	3,874	5.5
1973	5,371	7.8
1974	4,591	8.2
1975	3,372	8.1
1976	7,752	14.5
1977	4,748	11.2
1978	4,883	20.3
1979	4,313	16.0
1980	3,825	15.6

5 year average 1976-1980 -- 5,104

10 year average 1971-1980 -- 4,618

15 year average 1966-1980 -- 4,462

Aspen also occurs in the conifer types (table 1). Within the spruce-fir sawtimber type, aspen represents 5 percent of the cubic foot volume, or 3 percent of the board foot volume of the stands. In the Douglas-fir--white fir sawtimber stands, aspen represents 11 percent of the cubic foot volume or 7 percent of the board foot volumes. Aspen is almost totally absent from the ponderosa pine type, representing less than 1 percent of the cubic foot volume of these stands.

Table 3 -- Area of aspen by age class

Age class	Acres
0-20	60,022
21-40	14,209
41-60	67,844
61-80	33,624
81-100	3,623
101-120	25,498
121+	64,044
	268,864

Where mature aspen occurs as a part of a coniferous overstory, it is designated for harvest and required to be utilized on an individual tree basis, just as do the conifers. No attempt has been made to eliminate aspen as a component of these stands. Aspen has responded well to this treatment. There are sufficient overstory conifers to maintain the conifer type, and any small openings have regenerated to aspen. Thus aspen will continue to be an important component of these mixed stands.

Aspen occurs as an almost pure overstory in stands having a conifer understory. We have made overwood removal cuts in these by removing all aspen over 8 inches d.b.h. The response has been favorable; the understory conifers have increased both in diameter and height growth. Due to irregularities in stocking and to logging damage, advanced conifer reproduction seldom fully occupies these sites. Where openings occur, aspen reproduction has been quite abundant. Aspen will continue to be a strong component of these stands but the future stand will probably be typed as a conifer stand.

The majority of aspen occurs as essentially a pure aspen type. A variety of harvest techniques have been used in these stands. In the mid-1960's, a sale was let where only the merchantable trees were felled and removed. Sales in the late 1960's required all trees over a given diameter (either 8 or 10 inches) to be felled and removed. The response to this type of harvest is directly related to the amount of residual stand left after harvest. More recent sales in this type have required that all aspen trees over 2 inches d.b.h. be felled. Falling unmerchantable trees can either be the purchaser's responsibility, under the terms of the timber sale contract, or can be done by the Forest Service with deposited funds.

A series of aspen cuts made in 1965 and 1966 are worthy of mention. These stands were decadent at the time of harvest and only merchantable trees were harvested. This resulted in a residual stand of decadent trees and very light slash on the ground. The area has had unrestricted cattle use since harvest. Today, these areas have essentially converted to grass. Because of the partial cut, aspen reproduction was weak. Data are not available, but reproduction was probably 1,000 trees per acre. The overstory undoubtedly suppressed height growth of these trees; and cattle browsing and trampling damaged what reproduction did occur. Today there is no reproduction that can be considered potential crop trees. This system of management is not recommended if the intent is to produce crops of aspen. However, it appears to have merit if the intention is to reduce the area of aspen and increase the area of rangeland.

Other areas that have been cut to a minimum diameter limit, usually 10 inches d.b.h., have responded well and are now overstocked with potential crop trees. These stands were not decadent at the time of harvest. Generally, there were sufficient trees of merchantable size so that very little residual was left. Regeneration occurred and height growth has not been retarded. Residual basal area appears to have been in the range of 30 to 60 ft^2 per acre. Some of these stands have since been recut to remove the few residual trees from the original harvest. No significant damage occurred to the regeneration, and no significant additional suckering occurred.

Some, but not all, of the areas cut in the 1960's have received moderately heavy grazing use. The trees in these areas appear sound and well formed. Browsing was not heavy enough in these stands to restrict height growth. The trees are now 15 ft or taller and relatively safe from browsing damage. However, many of these trees have basal scars, probably caused by trampling. Most of these basal scarred trees have discolored heartwood that pathologists say is caused by unknown stain-causing microorganisms. Whether or not these organisms will prevent the trees from producing usuable sawlogs remains to be determined.

Since about 1970, sales in the pure aspen type have been true clearcuts. All aspen trees 2 inches d.b.h. and larger have been felled. The response has been impressive. Sprouting has occurred at the rate of 6,000 - 10,000 stems per acre. Commonly, at the end of the second growing season the dominant trees are 6 ft tall. Wildlife browsing is minimal and little cattle damage is evident. However, today, some trampling damage is apparent in these stands and staining is present in trees having basal scars. Since all of the trees were felled, the areas are more pleasing visually because the ragged appearance following commercial clearcutting is absent. The unmerchantable debris on the ground has created a barrier that discourages cattle use. Although this debris is now serving a useful purpose of discouraging cattle use, it remains to be seen if this debris will also discourage future silvicultural activity.

Harvesting the mature forest and obtaining regeneration is not an end in itself. Once regeneration is established, the new stand must be properly tended. Several research studies, along with local observations, show that unrestricted browsing and trampling can destroy a new sprout stand. Therefore, some measures must be taken to restrict this usage. In most cases, complete protection is not practical and probably is not necessary. The key seems to be restricted use, either by range management practices or by leaving sufficient debris so as to discourage animals from using the area. We're currently considering windrowing debris around the perimeter of clearcuts to serve as a fence to exclude livestock.

There is a wide spectrum of opinion regarding the desirability of precommercial thinning in aspen. Research papers can be found which support both sides of the question. We believe that precommercial thinning is desirable on the San Juan because our management is based on sawtimber production and many unthinned wild stands have reached rotation age while still in the poletimber size class.

In summary, management of aspen is tailored to one of three situations in which the species occurs on the San Juan National Forest: (1) mature aspen intermingled with conifer types is designated for cutting on a tree by tree basis along with the conifers; (2) in situations where mature aspen occurs as an overstory with a fully stocked conifer understory, all merchantable aspen is removed; (3) pure aspen stands are managed via a true silvicultural clearcut. The pure aspen situation has the greatest risk in that uncontrolled livestock use can destroy all or portions of the newly regenerated stand.

Demand for aspen from the Forest will continue to increase, and harvesting will be used more and more as a management tool to meet wildlife habitat and diversity needs. The future is full of opportunities to intensify management of aspen to help meet the many resource goals and objectives of the Forest.

ASPEN MANAGEMENT FOR FUELWOOD

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ABSTRACT

The forest land in this nation is a giant storehouse of energy. These lands produce fuelwood that ranges in quality from oak, which produces 31 BTUs per cord, to aspen, which produces 16 BTUs per cord. Where applicable, we as managers of public lands, can and should manage the forest lands for fuelwood output and thus contribute to our nation's energy needs. The demand is increasing. For example, on the Wasatch-Cache National Forest in the last 5 years free-use fuelwood permits have increased from 7,000 to 23,000, representing an increase in consumption from 90,000 to 33,000,000 bd.ft. This pressure created an opportune time to put aspen under management on the Forest. The selection of aspen sites to be harvested for fuelwood is governed by the following criteria: (1) site quality, (2) accessibility, (3) stand condition, and (4) aesthetic or environmental concerns.

The vast forests of the United States represent a giant storehouse of energy. They derive the necessary nutrients and water from the soil and energy from the sun to produce new wood fibers or stored energy (Garrett 1980). This stored energy in the form of cordwood provides fuel for many people. The types of cordwood most used by the residents of the western United States are the pines (ponderosa, pinyon, and lodgepole) along with Douglas-fir, western larch, and hardwoods. All of these are high in BTUs. The highest BTUs come from oak, which produces approximately 31 million BTUs per cord; aspen produces 16 million BTUs per cord (Robinson 1980).

To understand the relationship between the potential of forests for energy production and the demand, I have broken both into BTUs. The United States uses approximately 75 quadrillion BTUs--each quad equals 50 million cords of wood. If we satisfied our total energy needs by using the forests, we would completely remove all the trees from these lands in less than 7 years.

Wise management of our forests for energy would be to concentrate fuelwood use in rural and agricultural communities where local use may amount to 25 percent of energy needs in each community. In doing this, annual growth would easily offset wood consumption. This could easily be done in communities of 5,000 or less that lie adjacent to forested lands. If these communities would use only 4 quads or 200 million cords of fuelwood annually, it would contribute 5 percent of the total energy needs of the United States (Garrett 1980).

In the last few years several States, both east and west of the Mississippi River, have passed special legislation to encourage or improve the harvest of fuelwood. This special legislation is to insure the harvest and removal of cull, dead, and undesirable species. This practice helps improve growth and quality of the remaining stands.

Many publicly owned forests (Forest Service, BLM, and State) nationwide now have special management programs directed at producing fuelwood. One of these is the aspen management program on the Wasatch-Cache National Forest. This Forest and this program are used as examples throughout the remainder of this paper.

WASATCH-CACHE EXAMPLE

The impact for fuelwood on forest lands has increased greatly in the last 5 years. For instance, on the Wasatch-Cache National Forest in 1976 we issued 7,000 free-use fuelwood permits that accounted for removal of 90,000 bd.ft. of timber. In 1980 the same Forest issued 23,000 fuelwood permits that accounted for removal of approximately 33,000,000 bd.ft. of timber. This does not include the several thousand cords of commercial fuelwood sales.

In 5 years the number of permits issued had grown more than threefold; and the amount of wood removed under these permits had increased nearly 370-fold. In 1976 most users would gather one pickup truck or small trailer load for their annual supply. With only 13 bd.ft. per permit being taken in 1976, many permits must have been unused. In contrast, in 1980 approximately 1,400 bd.ft. of wood were taken per permit. Many users harvested their full allotment, going back for several loads under one permit.

This heavy use has put extreme pressure on us to furnish the goods and services demanded. With these pressures, we on the Wasatch-Cache felt that this was an opportune time to put the aspen stands under management.

We took the approach to management of aspen as being quite similar to management of other species. However, due to certain characteristics of aspen, there were a few things we could do that we could not with the conifers. If we cut and removed the aspen overstory, we would get the lateral roots to produce abundant suckers. These sucker sprouts are initially sustained by the root system of the parent tree until they can become firmly established and form their own root system. Because of this characteristic, the cost for timber stand improvement work was quite low. This type of clearcut management was initiated in the aspen on the Forest in 1978. The management areas were selected very carefully using the following criteria: (1) site quality, (2) accessibility, (3) stand condition, and (4) aesthetic or environmental concerns.

Site Quality

The better sites for aspen growth have the capability to produce saw logs with a yield of approximately 9000 bd.ft. or 45 cords per acre. The sites are characterized by having porous soils of sandy loam or silt loam texture. These sites will produce trees 70 to 80 ft in height at 50 years of age. The present stands on these sites are good indicators; however, the present unmanaged stands could be much older than 50 years.

Aspen also grows on some sensitive land forms and soil types in the Intermountain Region, including the Wasatch-Cache National Forest. These are fault lands and slump lands. These also are usually characterized by fine textured soils and oftentimes wet, imperfectly drained areas. Depending on the understory, clearcutting of the aspen on these soils can generate slumping. Therefore, a very careful check of the area, soil conditions, and vegetation is absolutely necessary prior to any commitment to clearcutting.[1]

Accessibility

The demand for aspen wood today on the Wasatch-Cache is such that any site selected for cutting must be quite accessible. It must be close or adjacent to a main travel road or highway. If close to a main road, there is less damage done to any pickup or other equipment required for transportation of the wood from the Forest, and turnaround time is much quicker.

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[1]Personal communication in 1981 from Paul Winkelaar, Forest Soil Scientist, Wasatch National Forest, Salt Lake City, Utah.

We must educate fuelwood users of the values of aspen. Then, in the future, we may be able to get fuelwood cutters to go anywhere on the Forest to help us meet our objectives for managing aspen stands.

Stand Condition

The condition of the stand is one of prime concern in the selection of harvest areas. Some aspen stands have reached their maturity in size and height and are starting to go downhill by becoming infected with wood rotting fungi. These fungi weaken the tree trunks and root systems and expose the stand to possible blowdown and wind breakage, or to attack by insects.

We now are inventorying the aspen stands as we do compartment examination work prior to timber harvest. These stand inventories will help us plan future fuelwood harvest areas in aspen. We will also plan for aspen to be harvested in the same areas as future timber sales. Then the users may remove the aspen as they do the slash from the timber sales.

Aesthetic or Environmental Concerns

Aspen harvest, as any other timber harvest, should fit into the landscape. The cutting units should be designed in irregular shapes so they blend into the rest of the surroundings.

During the last 2 years the Kamas Ranger District has harvested 25-35 acres of aspen within a quarter mile of the heavily used Mirror Lake Highway (Utah 150) without any adverse comments from other Forest users.

Another concern warrants discussion: Should we let fuelwood gatherers cut their own trees or should we fell the trees for their use? We are trying both methods on the Forest. We are concerned about the safety of users who may fall trees on themselves or others. Also, if they may cut green aspen in the designated area, will they cut them elsewhere where they are not supposed to? Since the Wasatch Forest has been into this fuelwood program, aspen fuelwood has been accepted by the forest users. Some of the favorable comments are:

1. "We use the new tight stoves and the wood is excellent in them."

2. "We like it because it doesn't soot up the chimney."

3. "Aspen burned in fireplaces without doors doesn't smoke up the house as does pine wood."

4. "The wood is cleaner for handling around the stove and woodbox than are conifers."

5. "The turnaround time is better. Coming from Salt Lake City, many times we can get two loads in one day."

With the demand for fuelwood, it is my hope that we as managers will not only be able to manage aspen stands better, but also make better use of other less desirable species as well, while helping with the total energy needs of this nation.

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OPPORTUNITIES FOR WILDLIFE HABITAT MANAGEMENT IN ASPEN

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ABSTRACT

The 16 National Forests of the Intermountain Region were contacted regarding their management activities designed to benefit wildlife in the aspen community. Fourteen Forests reported accomplishment of such projects. Most management activity has occurred since the mid-1970's. Prescribed fire and clearcutting have been the principal treatments utilized. The majority of aspen habitat treatments have been designed to improve conditions for mule deer, elk, and ruffed grouse as principal target species. Additionally, some 140 species (largely nongame), which are dependent upon aspen for breeding, feeding, or resting, will ultimately benefit. Future management should be based on the comprehensive, long-term cooperative efforts of State and Federal agencies.

Aspen (Populus tremuloides) is the most widespread deciduous tree in the western United States and is the dominant species on approximately 2 million acres in Utah, Nevada, southern Idaho, and western Wyoming (Smith and others 1972). In the Intermountain Region, it can be found growing up to about 10,500 ft in elevation and in precipitation zones ranging from 16 inches to over 40 inches. Although aspen can tolerate a wide variety of soil types, it thrives best in deep, loamy soils (Mueggler 1976).

The aspen community is well known for its recreational, range, watershed, and aesthetic values. It also has tremendous value as wildlife habitat, being used by some 140 of the 737 vertebrate wildlife species present in the Intermountain Region for feeding, nesting, or cover during some time of the year.[1]

Aspen is generally classified as a seral plant species, dominating an area until more shade-tolerant conifers invade the site (Mueggler 1976; Gruell and Loope 1974). This successional process generally takes from 80 to 400 years (Mueggler 1976; Bartos 1978). In the drier portions of its range, aspen may be replaced successionally by sagebrush-grass communities (DeByle 1978; Mueggler 1976).

Succession is stopped and aspen retained by catastrophe. Under natural regimes, wildfires were the usual catastrophic force (Wright and Klemmedson 1965; Gruell and Loope 1974). Aspen regenerates by suckers that grow profusely from existing root systems after a major disturbance such as fire. Although aspen usually produces abundant seed, moisture requirements of seedlings are such that they seldom survive in the Intermountain Region.

METHODS

Each of the 16 National Forests in the Intermountain Region were contacted regarding their management program to benefit wildlife habitat in the aspen community. Forest personnel were asked to provide the following information for any projects that occurred between 1970 and 1980: year project occurred; method of treatment; acreage; habitat objective(s); principal wildlife species benefitted; and whether there was any pre- and post-project evaluation. Additional opinions were requested about future management direction and important research needs.

CURRENT MANAGEMENT SITUATION

Fourteen of the 16 National Forests reported habitat manipulation in aspen to benefit wildlife during the period 1970-80 (table 1). There were some 115 individual projects conducted, affecting a total of 7,815 acres. Prescribed fire was the principal treatment used (5,385 acres); clearcutting was the second most common, occurring on 2,430 acres. Clearcutting was accomplished principally by Young Adult Conservation Corps or Youth Conservation Corps personnel (975 acres). Fuelwood harvest, where an area is designated for use by the public, was used on 245 acres. Commercial harvest of aspen occurred on 1,210 acres and was distributed among three Forests - Uinta, Dixie, and Sawtooth. There were no aspen areas treated with herbicides during the 1970's.

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[1] David S. Winn, personal communication.

Table 1.--Acres of habitat manipulation in aspen community, Intermountain Region National Forests, 1970-80.

Forest	Number projects	Prescribed fire	Clearcut: Cutting	Clearcut: Fuelwood Harvest	Clearcut: Sawlog	Total
Ashley	1	100	-	-	-	100
Boise	1	265	-	-	-	265
Bridger-Teton	23	810	302	-	-	1,112
Caribou	17	2,640	-	240	-	2,880
Challis	3	5	83	-	-	88
Dixie	6	250	-	-	1,100	1,350
Fishlake	6	500	-	-	-	500
Humboldt	-	-	-	-	-	-
Manti-Lasal	1	10	-	-	-	10
Payette	-	-	-	-	-	-
Salmon	1	5	-	-	-	5
Sawtooth	10	-	-	-	40	40
Targee	6	-	64	-	-	64
Toiyabe	6	600	50	-	-	650
Uinta	9	100	76	5	70	251
Wasatch	25	100	400	-	-	500
Totals	(115)	5,385	975	245	1,210	7,815

Approximately 90 percent of all acreage treated was accomplished since 1976. Project size ranged from 1 to 200 acres. Approximately 89 percent (6,922 acres) of total acres (7,815) treated during 1970-80 were on the Caribou, Bridger-Teton, Dixie, Toiyabe, Wasatch, and Fishlake National Forests.

HABITAT GOALS AND OBJECTIVES

It is the goal of the Intermountain Region to maintain aspen as a viable vegetative community. Accomplishing this will ultimately benefit all species dependent upon aspen for an important part of their habitat requirements.

All Forests reported specific management objectives for project activities. Commonly stated objectives are to:

- Increase forage quality, quantity, and availability

- Change distribution of age classes, providing for increased number of young stands

- Increase habitat diversity

- Maintain current distribution pattern of aspen

- Increase average aspen stand size

- Increase stem density stocking from present to some higher level within 5 years

- Decrease the conifer component

- Decrease stem size (d.b.h.)

PROJECT EVALUATION

All projects have had an environmental assessment (EA) prepared and approved as required by the National Environmental Policy Act. The purpose of the EA is to: (1) describe the proposed action and its impact on various resource values; (2) display various management alternatives; (3) allow for public involvement or comment; and (4) recommend a selected course of action.

In addition, approximately one-half of the projects have had either or both pre- or post-project evaluation of some type. Evaluation commonly consists of Ranger District personnel using temporary or permanent methods for sampling vegetation, soil conditions, or animal use. Photo plots, Parker 3-step, 3-way exclosures, and Cottam-Davis transects are frequently used. Evaluation has also consisted of monitoring by personnel of the Intermountain Forest and Range Experiment Station and the Idaho Department of Fish and Game. Currently, there are such cooperative efforts on the Caribou and Bridger-Teton National Forests.

Occasionally graduate students work on a research project associated with treatment in the aspen community. Currently, there are two such cooperative efforts. One is with Utah State University (Cooperative Wildlife Research Unit), Utah Division of

Wildlife Resources, and Forest Service (Wasatch National Forest); the other is with the University of Idaho, Idaho Department of Fish and Game, and Caribou National Forest.

ASSESSMENT OF PRACTICES

It appears that all methods currently utilized generally provide for a satisfactory level of objective accomplishment. Clearcutting consistently provides the greatest success in regenerating aspen. Other types of browse as well as herbaceous species also increase following this treatment.

Results from prescribed fire are somewhat mixed (from the standpoint of regenerating aspen), but there are far more successes than failures. Understory vegetation is always stimulated, with increased numbers of such browse species as woods rose (*Rosa woodsii*), snowberry (*Symphoricarpus oreophyllus*), serviceberry (*Amelanchier alnifolia*), as well as annual forbs.

Moderate intensity fires result in the greatest initial stimulation of aspen suckering (Bartos and Mueggler 1979; Horton and Hopkins 1966). Numbers of stems per acre generally reaches a peak during the second year following burning. High intensity fires rarely produce more than one-half the number of aspen sprouts as compared to the moderate intensity fire. However, understory forage production is fairly comparable between moderate and high intensity burns.

As a general rule, increased wildlife use is reported on treated areas. Examples from Forest personnel include elk, deer, blue and ruffed grouse, and bluebirds. There were no quantitative data provided to support these observations. However, the effect of clearcutting on bird populations is reported by DeByle (1981). Songbird populations were censused during early summer on 10 acres of aspen forest in the Chicken Creek watershed east of Farmington, Utah, for 2 years prior and for 2 years after clearcutting more than half the census area. He reported the decline or loss of five species (yellow-rumped warbler, warbling vireo, hermit thrush, gray-headed junco, house wren) and the increase or invasion of three others (bluebird, MacGillivray's warbler, and lazuli bunting).

Several researchers (Bartos and Mueggler 1979; Gruell 1979; Houston 1973; Mueggler 1976) report that an aspen burn must be of a large enough size to offset the effects of ungulate browsing. This is particularly important on winter concentration areas. Big-game animals and livestock are attracted to the lush new stands of suckers, and if these suckers are repeatedly browsed to a level in which more than about 30 percent of the seasonal twig volume is removed, the root reserves will become depleted and the stand will decline (Olmsted 1979).

Roots are sparse in extremely decadent aspen stands, and the resultant suckering after fire will be marginal. In these situations even light utilization can readily deplete the remaining root reserves and kill the clone. If these stands are to be rejuvenated, complete protection from browsing after burning may be necessary.

FUTURE MANAGEMENT DIRECTION

The Forest Service is in the process of developing land management plans for all administrative units on or before 1983. These Forest plans will provide broad management direction. It is important that cooperators (such as State wildlife agencies and the Bureau of Land Management) as well as the public, provide input regarding the importance of perpetuating aspen.

There is general recognition of the importance of the aspen community for a variety of values, including wildlife habitat. There is an increasing level of awareness among managers that the aspen resource throughout the Intermountain Region is not in a healthy state: there are more aspen stands passing out of the successional scene than there are young stands entering.

In order to achieve our management goal of maintaining aspen as a viable vegetative community, we will have to accelerate management activities in this type. To accomplish a quality, cost-effective job in the future we will need to:

- Gather better inventory data on stands

- Determine those stands that offer the highest probability for successful treatment

- Prioritize various projects

- Refine specific management objectives

- Encourage and utilize fuelwood (personal use) and commercial harvest as a management strategy

- Continue cooperative research efforts and monitoring of selected longterm administrative studies

- Develop and implement comprehensive, long-term, cooperative programs involving responsible State and Federal agencies

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CHANGES IN ASPEN AND ASSOCIATED SPECIES RESULTING FROM MANIPULATION BY BURNING AND CUTTING

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ABSTRACT

Monitoring the results of such management practices as burning and cutting the aspen ecosystem will contribute to our understanding and functioning of the system and serve as a basis for developing sound management alternatives. Knowledge of the system's response will aid managers in making decisions concerning various situations encountered. Five study sites in western Wyoming were burned (natural and prescribed) and a site in northern Utah was clearcut. Responses to these disturbances are being monitored to give us a better understanding of the initial stages of secondary succession.

Total undergrowth production the second year following burning doubled preburn conditions and then declined in subsequent years. On the cut areas, undergrowth production tripled after three growing seasons, while production on the uncut control areas increased only slightly. The number of aspen suckers peaked on the various sites from 9,000 to 160,000 suckers/ha and then declined to relatively stable numbers, except where heavy ungulate use virtually decimated the stands.

The purpose of our Forest Service research unit on the ecology and management of aspen is to develop and disseminate knowledge required to (1) perpetuate aspen forests as an integral part of western wildlands, and (2) enable management to produce the various balances of resources demanded by society from the aspen ecosystem. Understanding the effects of perturbations on the aspen ecosystem will contribute to our knowledge of the functioning of the system and serve as a basis for developing sound management alternatives. The most practical management alternatives for aspen lands at present are (1) permit aspen-to-conifer succession to proceed in seral communities; (2) use prescribed burning to set back plant succession and perpetuate aspen communities; (3) use clearcutting to harvest wood products as well as to set back plant succession; (4) grazing by livestock to harvest the forage resource.

Such perturbations and subsequent plant succession cause changes in resource values as well as other alterations in the ecosystem. The short- and long-term responses must be quantified to serve as the basis for sound land management decisions. This paper is limited to a brief discussion of burning and cutting the aspen ecosystem and the associated responses of the vegetation.

METHODS

Undergrowth production was measured at or near its peak at the end of July or the early part of August each year sampled. Production was determined by double-sampling microplots, 30.5 x 61 cm, which were distributed within and adjacent to each of permanently marked 100 m^2 macroplots. There were 40 macroplots on the burned site and 20 macroplots on the clearcut area. Capacitance meter readings (Currie and others 1973) were obtained on each microplot; then a portion of these were clipped by species. Regression equations that were developed for total production from only those plots both metered and clipped, permitted conversion of all meter readings to herbage production. All clipped material was dried at 70° C for at least 48 hours. A more detailed description of methodology is given by Bartos and Mueggler (1981; in press).

The majority of study sites were sampled less intensively. On these, permanent transects (2m x 30m) were established and monitored yearly to determine aspen response to disturbance by burning and cutting. Each year sucker density was recorded to determine the trend for aspen reproduction.

BURN

Fire appears essential to the rejuvenation of aspen stands in northwestern Wyoming (Gruell and Loope 1974). They hypothesized that decadent aspen stands could be renewed by prescribed burns even under heavy ungulate use. Currently, prescribed burns in aspen are being considered for inclusion in the management plan for the Bridger-Teton National Forest as well as for other Forests in the mountainous West.

Between 1974-1976 four prescribed burns and one natural fire (Water Falls site) occurred near Jackson Hole in western Wyoming (fig. 1). The major study site was Breakneck Ridge, approximately 50 km northeast of Jackson, which was burned on August 29, 1974. This site was sampled for total forage production and sucker response in 1974 (preburn) and in 1975, 1976, 1977 (postburn). Permanent transects were established here as well as on the other four sites (Russold Hill, Uhl Draw, Burro Hill, and Water Falls) shortly after burning. These sucker transects have been monitored on a yearly basis since establishment.

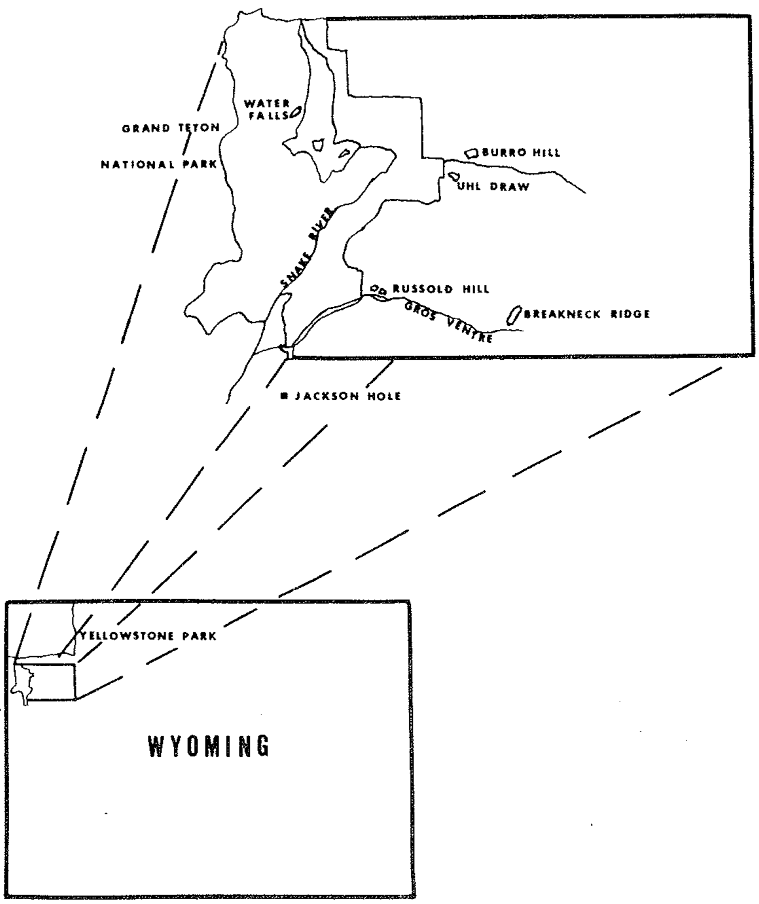

Figure 1.--Location of four prescribed burn sites (Burro Hill, Uhl Draw, Russold Hill, and Breakneck Ridge) and one wildfire (Water Falls) in the vicinity of Jackson Hole, Wyo.

For the Breakneck Ridge site, a plot was considered lightly burned if an estimated 0 to 20 percent of the litter and duff was consumed, moderately burned if 21 to 80 percent was consumed, and heavily burned if 81 to 100 percent was consumed. Most of the understory vegetation was scorched or consumed and up to 90 percent of the aspen trees were killed on the moderate burn, whereas all of the understory vegetation was consumed and over 90 percent of the aspen were killed on the heavy burn.

Annual production of undergrowth vegetation prior to burning was almost 1,800 kg/ha (fig. 2). After compensating for the effects of weather-induced differences, production decreased about one-third the first year after burning, and then increased substantially. By the second year following burning, understory production averaged about two-thirds more than before the areas burned. Production then decreased the third year to only about one-third more than before burning. Initial results of data collected in 1980 indicate this decline did not continue but remained at the 1977 level.

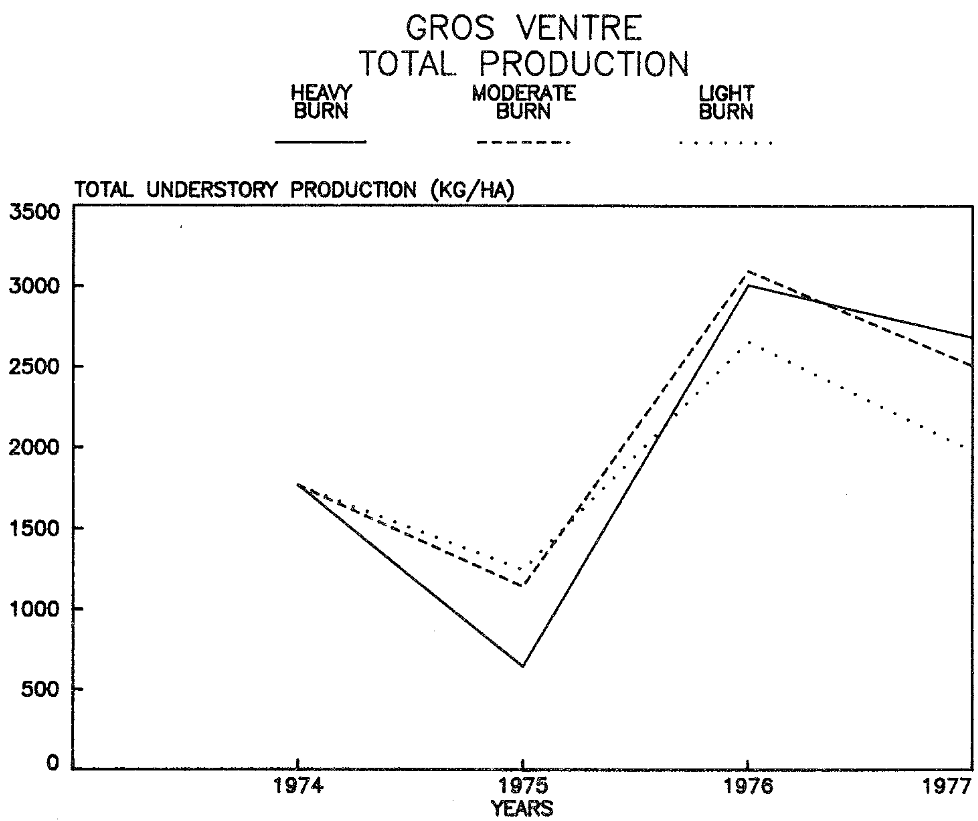

Figure 2.--Total undergrowth production for 3 years following burning at three intensities (Bartos and Mueggler 1981).

The different fire intensities responded similarly. By the third year after burning, the lightly, moderately, and heavily burned areas were producing 12, 42, and 52 percent, respectively, more total undergrowth production than before burning.

Prior to the burn, undergrowth production consisted primarily of forbs: with forbs = 68 percent, grasses = 15 percent, and shrubs = 17 percent. After burning, there was a greater shift in favor of forbs, primarily fireweed (Epilobium angustifolium). This shift was at the expense of the shrubs. By the end of the third postburn year (1977), total undergrowth production consisted of 80 percent forbs, 16 percent grasses, and 4 percent shrubs.

Figure 3 shows the aspen suckers produced on five burned areas for the past 5 to 6 years. The three upper curves (Burro Hill, Russold Hill, and Uhl Draw) show a typical response of aspen to burning; sucker numbers come in at a high level (40,000-150,000/ha) the first year after disturbance and decline to a fairly stable level. This rate of reproduction is believed adequate to perpetuate the aspen stands. The wildfire at the Water Falls area occurred on a poor aspen site. The suckers produced remained relatively stable over the five post-fire sampling seasons, varying between 9,000 and 6,000/ha. The most dramatic changes occurred on the Breakneck Ridge transects. Here sucker numbers peaked the second year following the fire with 32,000/ha, they then declined rapidly until in 1980 only 2,500/ha remained.

Large numbers of wild ungulates appear to have confounded sucker response on the Breakneck Ridge site. There is a winter feed ground for elk just adjacent to the burned area and these animals apply heavy browsing pressure that apparently is causing the aspen suckers to largely be eliminated. It is believed that this continued pressure will cause the demise of aspen clones in the vicinity of the feed grounds by the turn of the century.

CUT

In 1974, approximately 11.5 ha of aspen were clearcut on the Chicken Creek Watershed, Wasatch National Forest, located approximately 22 km northeast of Salt Lake City, Utah (fig. 4). The area is dominated by aspen with a lush understory of forbs and graminoids that have not been grazed by domestic livestock for the past 50 years. This clearcutting operation provided an opportunity to study early successional trends following the cutting of aspen-dominated communities. Both undergrowth production and sucker responses to cutting were measured.

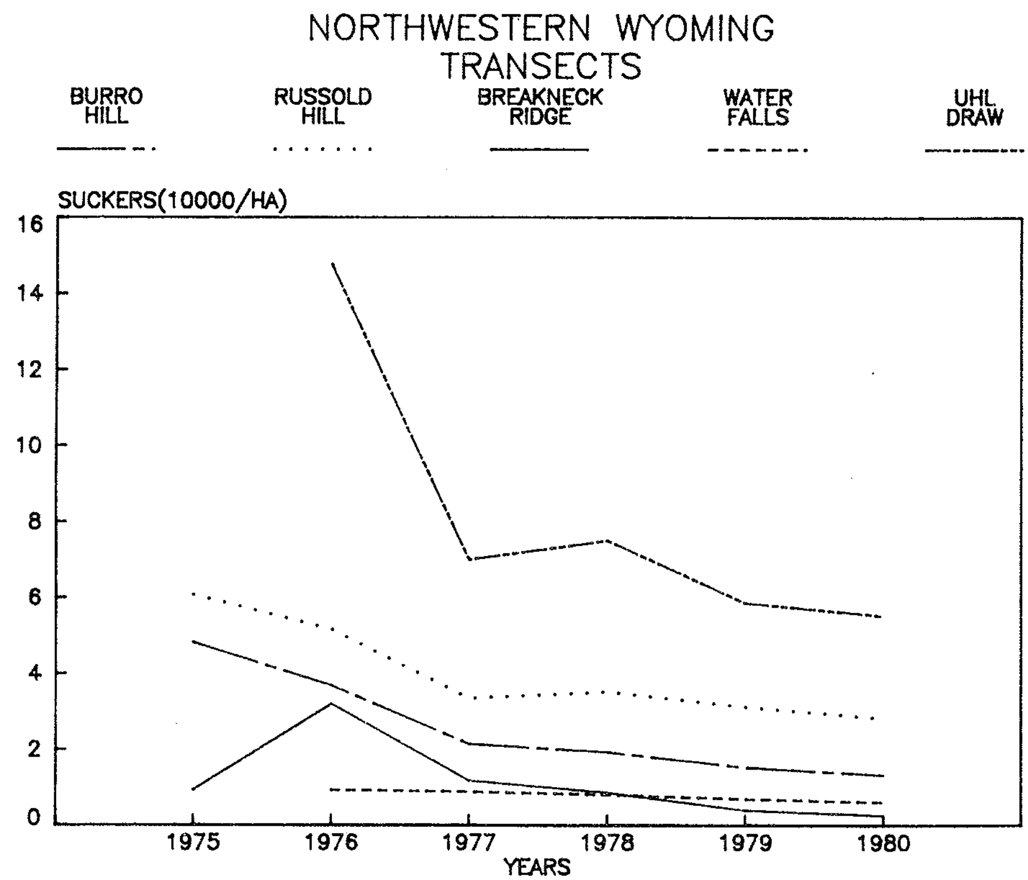

Figure 3.--Sucker response on four prescribed burns and one natural fire (Water Falls) in northwestern Wyoming for 1975-1980.

All trees over 5.1 cm diameter at breast height (d.b.h.) were cut (approximately 15,000 m^3/ha) and all usable boles were removed from the site for firewood. To minimize site disturbance, horses were used to skid the boles, but the slash was left in place.

In 1973, prior to cutting, total undergrowth production was about the same on the cut and uncut units with both producing approximately 1,100 kg/ha (fig. 5). On the uncut control areas, production increased 28 percent; and after 3 years these sites had 1,500 kg/ha of undergrowth production. This small but statistically significant increase in production on the control areas was probably the result of natural variations in weather.

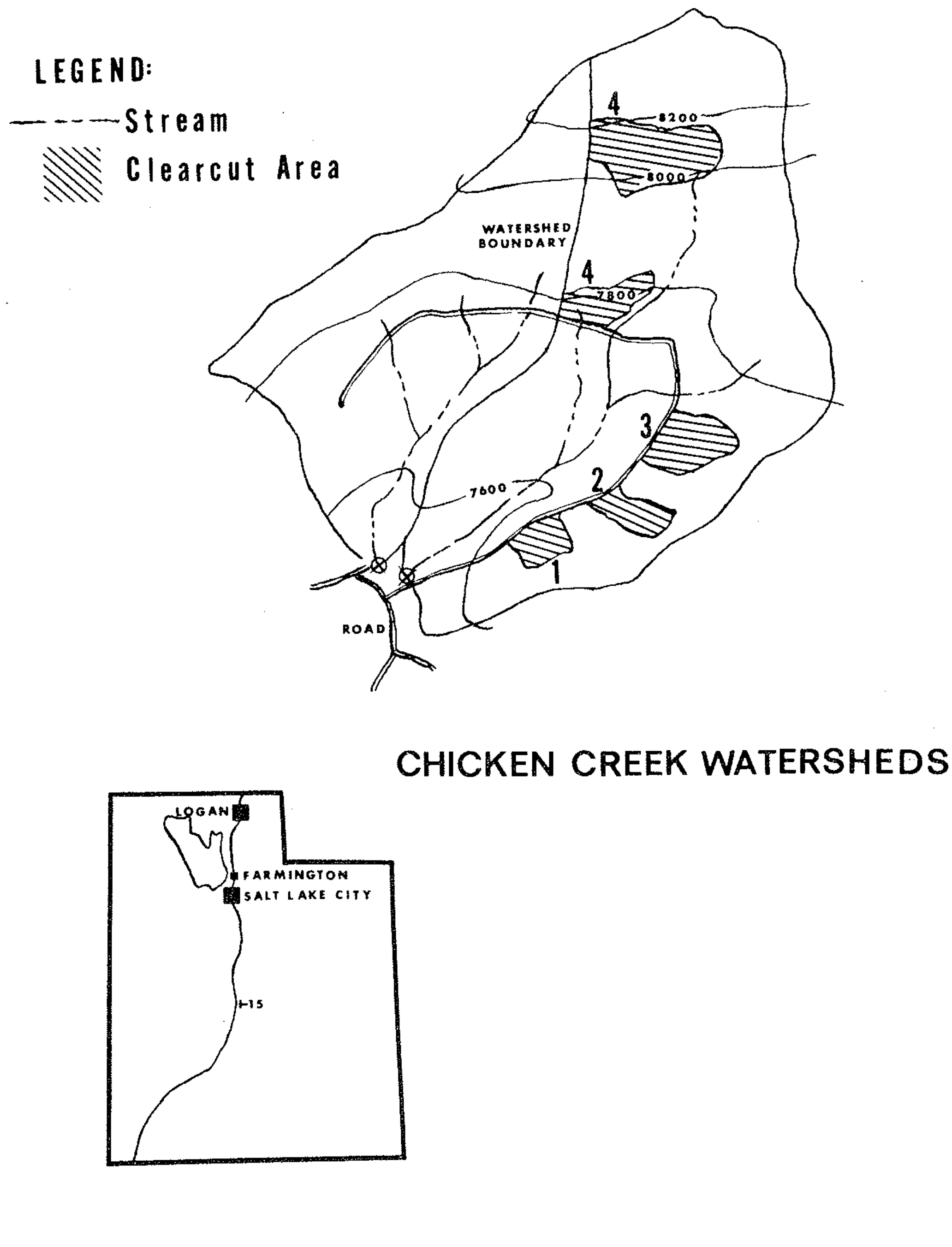

Figure 4.--Location of five cut units on the Chicken Creek site of the Davis County Experimental Watershed. The study site is located approximately 22 km northeast of Salt Lake City, Utah.

On the cut areas, however, the undergrowth production trebled to approximately 3,000 kg/ha (fig. 5) by 1977. This large increase in production on the cut areas is probably a combination of the effects of weather and release from competition caused by clearcutting. In each of the 3 years following cutting, production of undergrowth was significantly greater on the cut than on the uncut control area. By the third postcut year, the clearcuts were producing twice as much total shrubs, forbs, and graminoids as the uncut aspen forest.

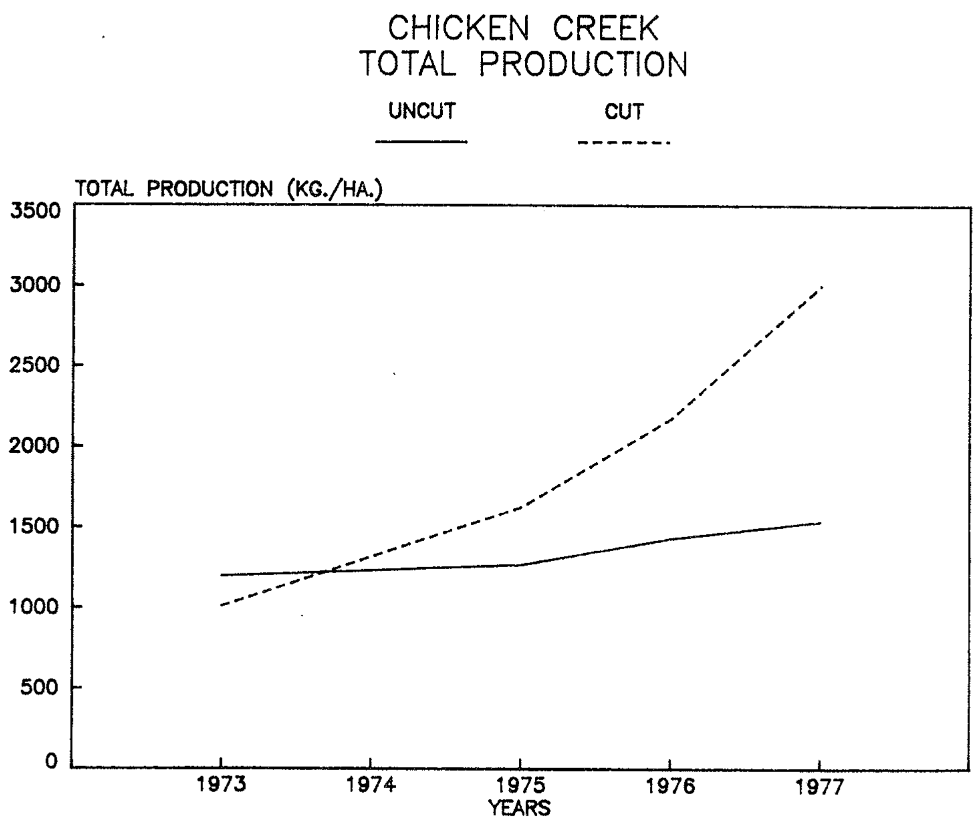

Figure 5.--Changes in production (kg/ha oven dry weight) of undergrowth on clearcut aspen and uncut control areas in 1973 before cutting 1974, and during the first 3 years following cutting (Bartos and Mueggler, in press).

Perennial forbs contributed approximately 50 percent to the total undergrowth production both before and after clearcutting. The remainder of the production consisted of 20 percent grasses and sedges, 20 percent shrubs (excluding aspen reproduction), and 10 percent annual forbs.

Early succession following clearcutting of aspen communities is characterized by a significant increase in the amount of all undergrowth vegetation. This increase is attributed to the reduction in competition from an aspen overstory. As succession proceeds and aspen regains dominance, it is expected the upward trend in production will level off and then gradually decrease. Aspen suckers grow rapidly following clearcutting and may begin to suppress production of undergrowth within a relatively few years.

The number of aspen suckers remained fairly constant on the uncut areas throughout the study period, varying from approximately 1,400 to 4,300/ha (fig. 6). These suckers remained small and contributed little to the total current year's production of undergrowth. As expected, clearcutting the aspen overstory stimulated profuse suckering of aspen, particularly the second growing season following cutting. Sucker numbers increased from 2,300/ha before to 8,500 the first postcut year, and to a maximum of 44,000 the second postcut year. Numbers of suckers dropped the third postcut year to approximately 25,000/ha. The 20-fold increase in sucker production is similar to what Mueggler and Bartos (1977) reported for an aspen clearcut in southern Utah. Smith and others (1972) reported 74,000 to 124,000 suckers/ha after clearcutting aspen in northern Utah. Jones (1975) found 35,000 suckers/ha on aspen clearcuts in Arizona; in southwestern Colorado, Hittenrauch (1976) found 15,000 to 25,000 suckers/ha. Jones (1976) indicated that 50,000 to 75,000 suckers/ha is not excessive because of the natural thinning that occurs in aspen stands. A mature stand of aspen on this Chicken Creek area contains from 700 to 3,600 stems/ha.

CONCLUSIONS

It was found that burning and cutting the aspen ecosystem stimulated undergrowth production at least temporarily. On the burned areas, total undergrowth production doubled preburn conditions with approximately 3,600 kg/ha being recorded the second year after treatment. There was, however, a decline in production in subsequent years. On the clearcut area, the undergrowth production trebled to approximately 3,000 kg/ha by the third posttreatment year.

On the burned sites, there was a shift in species group composition. Forbs increased from 68 percent prior to burning to 80 percent by the end of the third postburn year. Shrubs, however, decreased from 17 percent prior to burning to only 4 percent 3 years later, and grasses remained relatively constant at 15 percent for all years sampled. The increase in forbs was attributed in part to one species, fireweed. On the clearcut site in Utah, the species composition did not change appreciably as a result of disturbance. For all years sampled, the total undergrowth production consisted of 50 percent forbs, 20 percent grasses and sedges, 20 percent shrubs, and 10 percent annual forbs.

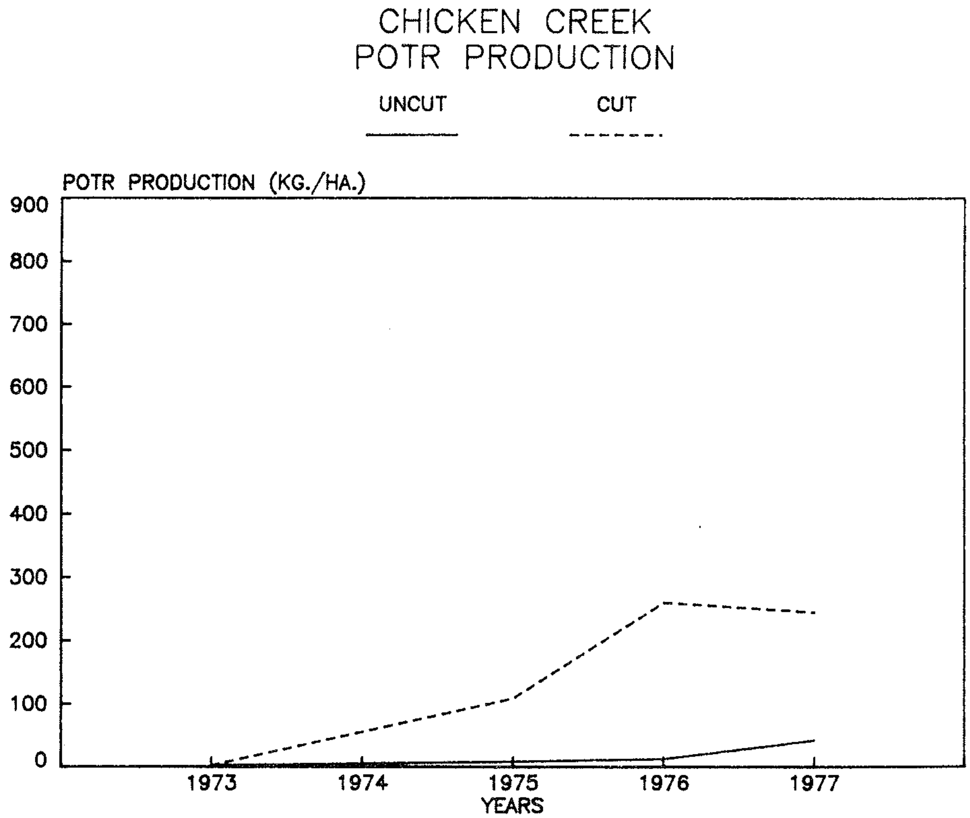

Figure 6.--Changes in the number of aspen suckers on clearcut and uncut control areas in 1973 before cutting in 1974, and during the first 3 years following cutting (Bartos and Mueggler, in press).

All sites, both burned and cut, produced sufficient aspen suckers to regenerate the aspen stands. Peak sucker numbers vaired between 9,000 and 15,000 suckers/ha. Because of mortality and competition, these numbers have declined but generally are at a level that should adequately replace the stands. The exception is the Breakneck Ridge site, which produced 32,000 suckers/ha the second year after burning and then declined rapidly until in 1980 only 2,500/ha remained. Personal observations in June 1981 showed that the numbers of suckers have been reduced further. This situation is attributed to the pressure applied to the study site by large numbers of ungulates (primarily elk). I believe that decadent aspen stands can be rejuvenated by burning except where large numbers of ungulates are concentrated and are applying pressure at critical times of the year.

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A SUCCESSION MODEL AS A POTENTIAL AID FOR MANAGING ASPEN UNDER DIFFERENT SITUATIONS

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ABSTRACT

Using existing data and intuition, a simulation model (Bartos 1973, 1978) was developed as an aid to understanding the dynamics of the aspen system. Further refinement of the model has been accomplished by reducing model complexity. The numbers of parameters in the original model has been reduced appreciably while still retaining the structure and behavior appropriate to the system. Sensitivity of parameters to change has been analyzed and is reported here. The final product sought is a predictive model of aspen succession that the resource manager can use as an aid in making decisions concerning aspen under different situations.

The aspen (Populus tremuloides, Michx.) ecosystem is prevalent in the Intermountain West (Little 1971) and produces multiple resources. To manage the aspen system and its resources intelligently, we must understand the natural forces acting upon and within the aspen ecosystem. Once we understand the dynamics of the vegetation, we can make valid judgments concerning the use of these lands by wildlife and domestic livestock. Also, the process of succession needs to be better understood so that the successional position of a particular stand can be identified and the stand managed accordingly.

According to Mueggler (1976), the aspen type can succeed to either conifers or sagebrush-grass, or it can remain stable, that is, dominated by aspen. No matter which process occurs, it still requires a considerable length of time (in excess of 200 years) to "achieve" a climax situation. Long-term intensive studies are not feasible to answer pressing and current management problems. Using existing data and intuition, a simulation model (Bartos 1973; 1978) was developed as an aid to understanding the dynamics of the aspen system. This initial model has been revised by reducing the number of parameters, while retaining the structure and behavior of the model.[1] The sensitivity of the model to change of parameters has been analyzed and is reported here.

MODEL OBJECTIVES

The objective of our effort was to develop a streamlined simulation model that would predict the dynamic nature of the vegetation components within the aspen system and how these components change during the successional process. This model should be applicable to most aspen lands in the western United States and should be an aid to natural resource managers in their decision-making process.

There are several key points in this objective statement that require further elaboration. First, dynamic implies changes in the various vegetative components of the system over time. Second, vegetation component refers to only the aboveground biomass for wood (aspen and conifers) and forage (shrub and herb species). Third, successional process is the dynamics of a vegetative unit as it progresses toward a community that is in a steady state (climax) relationship with the environment. We are concerned with only secondary succession--where the soil may remain at a fairly advanced stage of development while the plant community is set back to an earlier stage because of a disturbance. Last, general model implies flexibility to apply the model to different sites with similar environmental conditions. The model needs to assimilate disconnected bits of information and predict reasonably accurately the results of management practices.

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[1]The authors express their gratitude to George Innis, Utah State University, for his direction and assistance in this effort for the past several years. We also thank the following members of the Intermountain Station's work unit on ecology and management of aspen lands for their assistance and suggestions: Robert Campbell, Norbert DeByle, Roy Harniss, Walter Mueggler, and George Schier.

While this objective statement sets the general tone of the modeling effort, a more explicit set of issues must be addressed:

1. Does the modeled successional pattern fit the intuition of experts?

2. Does the model respond reasonably to management actions?

3. Without major influences from conifers and herbs, is aspen able to stabilize for long periods of time?

4. What are the sensitivities of these predictions to parameter estimates, site condition assignments, initial conditions, functional forms of flows, and so forth?

5. What additional research is needed to make the model a more accurate description of succession?

Though there are many other succession models, none of them address the management objectives stressed here. Botkin and others (1972) used stochastic processes to explain relative abundance of different species at various locations in an eastern hardwood forest. This type model follows the history of each tree in a small plot. Its emphasis is more toward biology than management. Another type of model, exemplified by Stage (1973), is a regression model that computes growth of a particular species established on a site. This model is much more applicable to a tree farm operation than to aspen forests of the Intermountain West, where concern is with relative abundance of system components over time. Nobel and Slatyer (1977) model species presence following a fire. Biomass estimates, from which values of the system for timber, grazing, or wildlife can be inferred, are not included.

ASSUMPTIONS

Several assumptions were made to facilitate initial model development and subsequent updates. The initial assumptions are as follows: (1) The system stressed will have conifers on or near it providing a seed source for conifer seedlings once the site is disturbed. (2) Aspen are present; therefore, a root source exists to provide a flush of aspen suckers once the site is disturbed. (3) The damaged site will be small enough to be homogeneous with respect to soil characteristics and abiotic factors. (4) Disturbance will be by burning; some root crowns of perennial herbs will not be killed and total herbs will be temporarily stimulated once the site is manipulated. (The site could quite conceivably be stressed by cutting the overstory trees and similar responses might be observed.)

MODEL STRUCTURE

The major components of this model are aspen, conifers, shrubs, and herbs (annual and perennial). These regenerate, grow, and die at rates affected by the various compartments as summarized in figure 1. The mathematical model is a set of simultaneous difference equations. The model was coded in FORTRAN V and runs on the Burroughs 6800 at Utah State University.

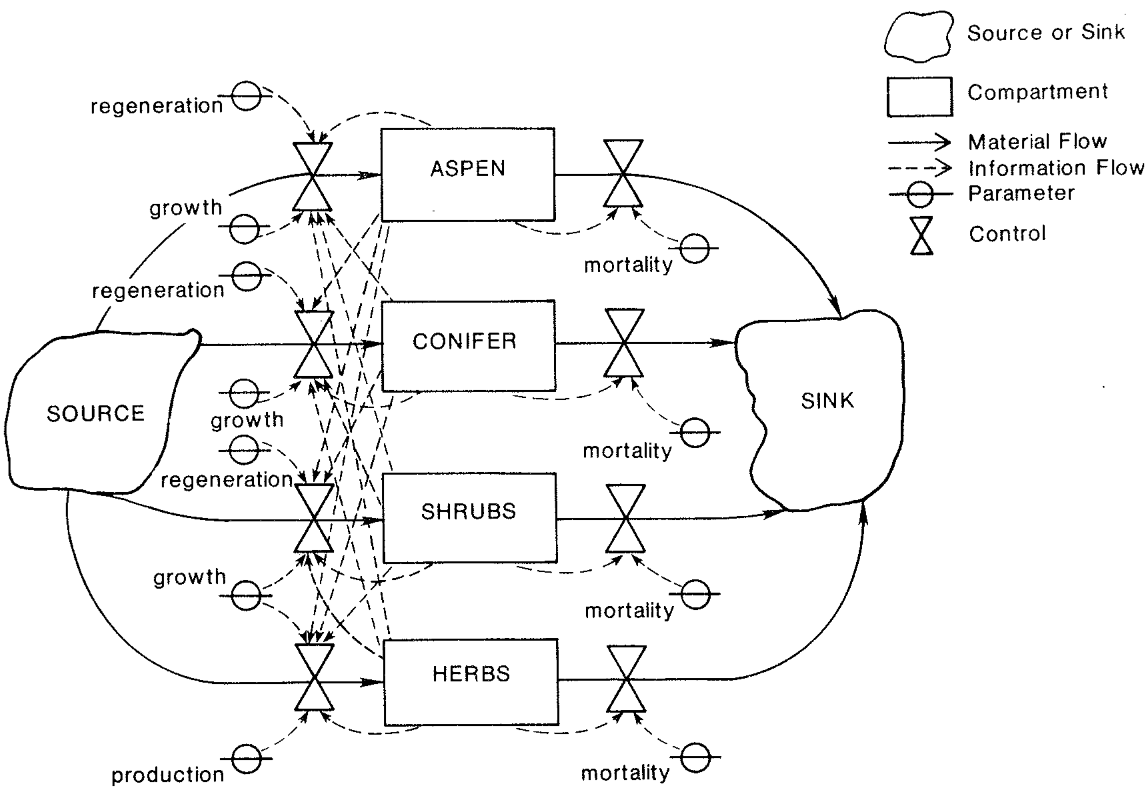

Figure 1.--Summary flow diagram of major compartments in ASPEN model.

In this paper "mortality" refers to a loss of live material and includes death of portions of trees as well as death of entire trees. This takes into account the loss of lower limbs as well as occasional loss of entire trees. To simulate a high mortality rate due to disease or insects, the run is terminated and restarted with initial conditions that reflect the appropriate conditions.

The complete flow diagram of the model structure is quite complex and difficult to interpret. A general idea of the structure can be obtained from inspection of a part of the model, that portion dealing with perennial responses. A flow diagram for these is shown in figure 2, where conventions used are from Innis (1979).

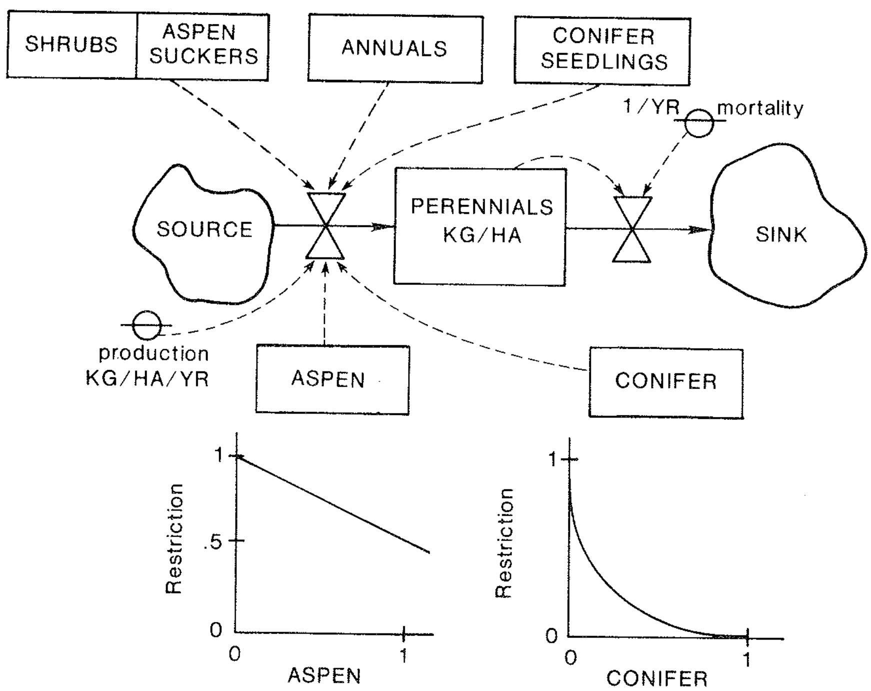

Figure 2.--Flow diagram for PERENNIAL production and mortaltiy with graphs of influence of aspen and conifer compartment on perennial productions.

*Horizontal axis shows ratio of present to maximum possible value of the designated compartment.

Several compartments affect the production flow into the perennial compartment and the mortality rate is assumed to be 100 percent per annum. The production rate parameter represents the maximum possible production in a given year. This rate, however, is modified by each of the other compartments shown. The influence of aspen and conifer on the production rate of perennials is also shown graphically in figure 2. When its biomass is zero, the inhibiting compartment offers no restriction on perennial production (the restriction factor is 1), but as biomass of the inhibitor increases, the restriction becomes more stringent (the restriction factor drops well below 1). Algebraically, the production rate is as follows:

$$\text{Production rate} = P * Z1 * Z2 * Z3 * Z4 * Z5 * Z6$$

where

P = maximum production rate (3,500 kg/ha for our site)
Z1 = aspen overstory restriction
Z2 = conifer overstory restriction
Z3 = shrub restriction
Z4 = annual restriction
Z5 = aspen sucker restriction
Z6 = conifer seedling restriction

A more comprehensive discussion of the model is in preparation as a research paper by the Intermountain Forest and Range Experiment Station.

Aspen, conifers, and shrubs are treated in a more complex fashion than the perennials (fig. 1). In these cases, production is separated into regeneration and growth, both of which can be affected by various model compartments. Each of aspen and conifer reproduction is divided into three components, and for each component we consider graduation and mortality.

Both the regeneration and growth rates are affected by the biomass of various compartments in the preceding year. For each compartment, however, the mortality is a fixed proportion of the biomass. A net increase in biomass is realized when the growth rate exceeds the mortality rate, and a net decrease occurs when the growth rate, because of various restrictions, is lower than the mortality rate. During the model building process there was much discussion as to whether in a stand (1) the mortality rate increased to surpass the growth rate, (2) the growth rate dropped below the mortality rate, or (3) the growth rate decreased over time as the mortality rate increased. In the absence of firm knowledge of what actually takes place, it was decided to hold mortality constant and decrease growth from some maximum value by means of the various restrictions. In the conifer compartment a 2 percent mortality rate is allowed so that maximum net loss would be 2 percent per year.

MODEL RESULTS

Model results for 400 years following a hot fire are shown in figure 3. In this "standard run," we assume that maximum biomass possible for aspen is 200,000 kg/ha, for conifer 250,000 kg/ha, for shrubs 10,000 kg/ha, and for herbs 4,000 kg/ha. While peak aspen biomass (191,000 kg/ha) occurs in the 132nd year, the aspen biomass exceeds 190,000 kg/ha for approximately 40 years. The conifers come in much more slowly and do not become dominant until nearly 300 years after the disturbance. After 400 years, the conifer biomass is 192,000 kg/ha and still increasing slightly. The shrubs peak in the 80th year with 7,000 kg/ha and the herbage peaks the 8th year with a biomass of 2,500 kg/ha.

By changing the maximum rate at which conifer seedlings become established from 1,000 to 10,000, an earlier dominance of conifer is obtained (fig. 4). This results in an earlier suppression of the other compartments and a shorter time for conifer to approach its maximum. Though such behavior may occur in the Intermountain area, it is probably more typical of aspen woodlands in the Upper Midwest. If conifer seedlings do not become established (no seed source), the values in the other compartments remain much higher (fig. 5) throughout the simulation run.

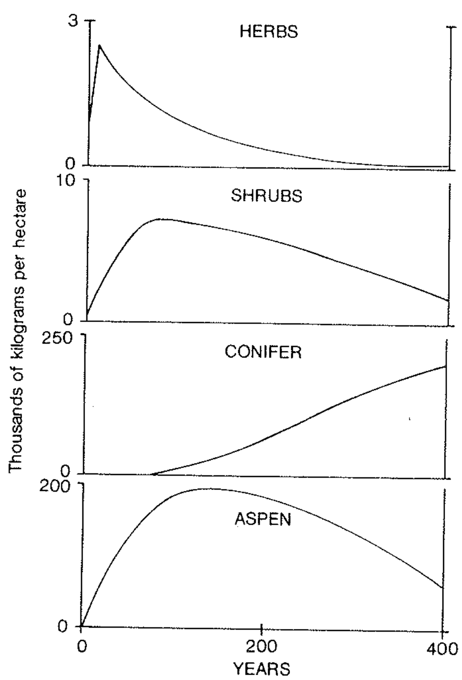

Figure 3.--Biomass of four major system components graphed against time for "standard run" in which all parameters areat nominal levels.

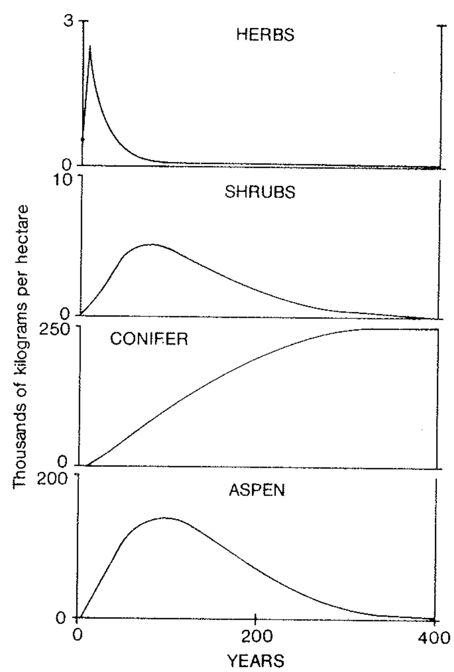

Figure 4.--Biomass of four major system components graphed against time for case similating rapid regeneration of conifer.

In figure 6, an aspen harvest is simulated at 90 years in the successional process in order to favor conifer production on the site. Conifer growth is shown to be enhanced by that harvest; in just 270 years it attains the value achieved in 400 years in the standard run, and after 400 years it is close to its maximum biomass. Immediately after the aspen harvest, the shrubs and herbage increase but are quickly suppressed again by the rapidly growing conifers. Aspen comes in again after the harvest but peaks at only 85,000 kg/ha and is almost eliminated by the 400th year.

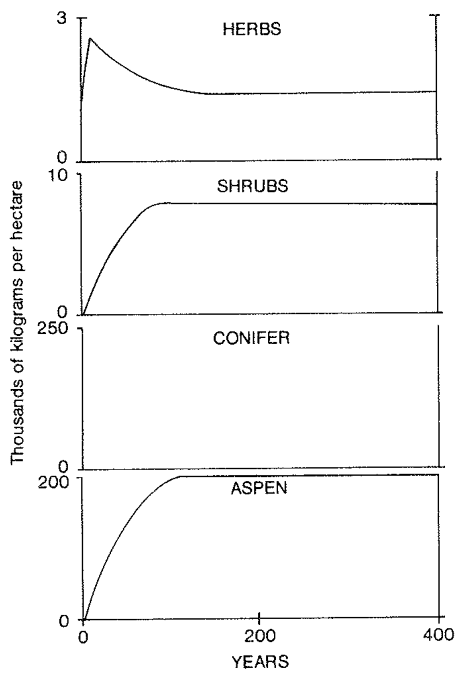

Figure 5.--Biomass of four major system components graphed against time for case in which there is no conifer regeneration.

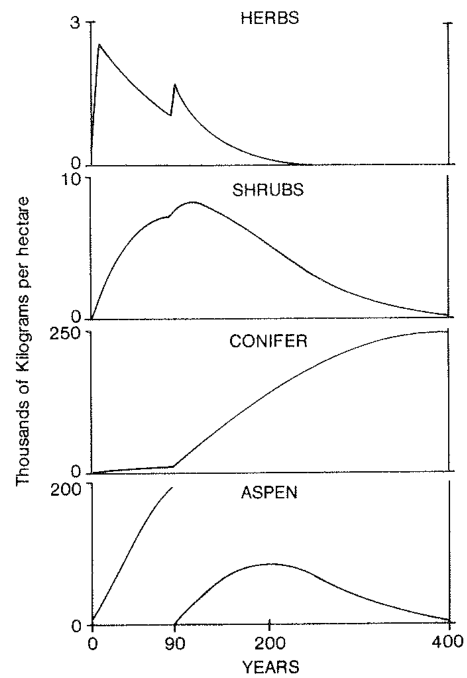

Figure 6.--Biomass of four major system components graphed against time for case in which aspen is harvested at 90 years.

A more typical clear-cutting situation is shown in figure 7. Here all the overstory conifers and half the conifer seedlings are removed at 300 years. Also, half the mature aspen biomass is removed by harvesting. The next 300 years are very similar to the first 300 except that aspen peaks a little more quickly and at a somewhat higher value. One should bear in mind that this peak does not represent the even-aged stand represented by the first peak.

The major shortcoming of the model is lack of confidence in the parameter values used. It is quite possible that widely differing sets of parameters can give very similar model results. On the other hand, slightly differing parameters can yield widely differing results. To demonstrate the degree of uncertaintly in the model, 30 simulation runs were made that were variations on the standard run. Parameters for the maximum production rates of annuals and perennials and maximum values of the five compartments (aspen, conifers, shrubs, annuals, and perennials) were fixed for the "typical" site investigated. Also, the initial number of conifers was held at zero. At the start of each of the 30 runs, each of the remaining 130 parameters was picked at random from a uniform distribution over its range of uncertainty and held at that value for the duration of the run. Choice of parameters was not always completely random, however, for there were some such checks to ascertain that the sum of relative flow rates from a compartment did not exceed 1 and that aspen growth rate never exceeded the conifer growth rate. The basic shapes of the resulting graphs were much the same in all cases. That is, if appropriately different scales were used for the 30 graphs, they would be quite similar in appearance. There is a fairly wide response range in the 30 runs as is demonstrated in figure 8, which gives the maximum, minimum, and mean values at each year.

SENSITIVITY ANALYSIS

In a test of sensitivity to parameter change, the parameters mentioned in the preceding section were altered one at a time by an amount that reflected the largest possible error in that value. Change in the peak value for each compartment was recorded as was the change in time at which the peak occurred. This exercise indicated that while the model is fairly insensitive to changes in some of the parameters, it is quite sensitive to changes in others. The model is most sensitive to the growth and mortality rates for aspen, conifers, and shrubs; the restriction of aspen on conifer growth; and the restriction of conifers on aspen growth. For instance, and increase in the annual growth rate of conifers from 7 to 8 percent can significantly reduce the peak value of aspen biomass and decrease the time required for conifers to reach 200,00 kg/ha.

A change from .5 to .35 in the maximum restriction of aspen on conifer growth can significantly alter the time frame of succession. Aspen dominates the system throughout the run, and conifer biomass is only 65,000 kg/ha after 400 years. Further investigations of these relationships indicated one could raise conifer growth rates from 7 to 8 percent, raise conifer mortality rate from 2 to 3 percent, lighten the restriction of aspen on conifer growth appropriately, and get almost no change at all in the model results.

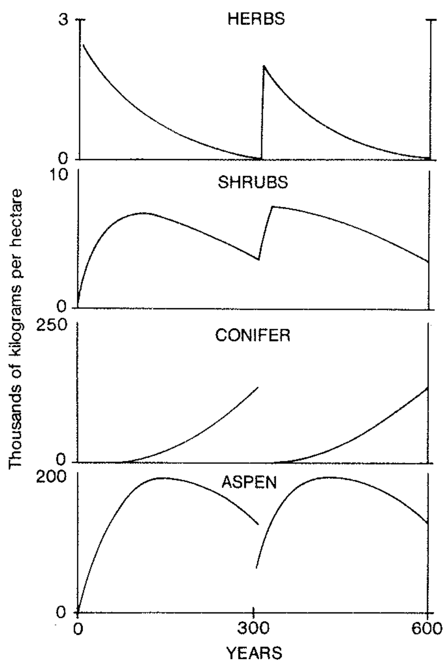

Figure 7.--Biomass of four major components graphed against time for case in which conifer and aspen are harvested at 300 years.

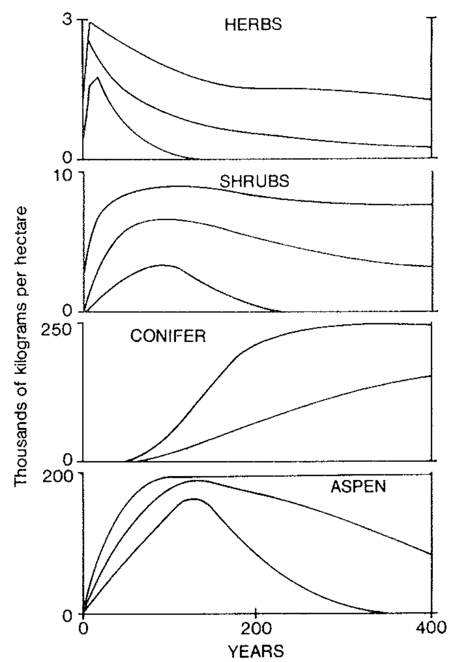

Figure 8.--Biomass of four major system components graphed againsttime. High, low, and mean values of 30 runs with randomly perturbed parameters are shown.

CONCLUSIONS

At this point it appears that the model in its standard form fits reasonably well the intuition of experts. Also, it seems to respond in an appropriate fashion to management manipulations. The authors would feel much more comfortable with the model if they had substantial data on the growth and mortality rates of the aspen, conifers, and shrubs, and the way in which aspen and conifers affect the growth of each other.

The model can be parameterized for many sites, but the parameters used in this effort reflect a site of "average" potential. Other sets of parameters should be derived to reflect sites with greater or lesser potential.

In the current version of the model, the site succeeds to conifer domination unless there is no conifer seed source, in which case the site climaxes in aspen. It would be helpful to allow for the possibility of aspen succeeding to sagebrush-grass as well.

The model has been refined and a better understanding of the dynamics has resulted, but further refinement and verification are needed. In its present form, the model is primarily a tool for directing research efforts, but we hope to be able to narrow the confidence bands on the predictions sufficiently to make it a useful tool for land management decisions.

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